

LEVEL II

(12)

B.S.
NRL Report 8426

AD A092607

**Proceedings of an AAAS Symposium on January 8, 1980:
How Much Does the
Defense Department Advance Science?**

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September 24, 1980

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
14. REPORT NUMBER NRL 8426 ✓	2. GOVT ACCESSION NO. AD-A092	3. RECIPIENT'S CATALOG NUMBER 607	
6. TITLE (and Subtitle) PROCEEDINGS OF AN AAAS SYMPOSIUM ON JANUARY 8, 1980: HOW MUCH DOES THE DEFENSE DEPARTMENT ADVANCE SCIENCE?		5. TYPE OF REPORT & PERIOD COVERED Final report on a symposium.	
7. AUTHOR(s) George Gamota, Alan Berman, Edward Salkovitz, Edward Teller, George Wald, and David Triantos		6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		8. CONTRACT OR GRANT NUMBER(s)	11. 24 Sep 80
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, VA 22217		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	12. REPORT DATE September 24, 1980
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 36	15. SECURITY CLASS (of this report) Unclassified
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES *Office of the Under Secretary of Defense for Research and Engineering †Office of Naval Research ‡Lawrence Livermore Laboratory §Harvard University			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Laboratories Policies Weapons Research management History Nuclear weapons Contract administration Military research Warfare Research Naval research Arms control Universities			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains the proceedings of a 3-hour symposium given January 8, 1980, during the annual meeting of the American Association for the Advancement of Science at the San Francisco Hilton Hotel. The speakers discussed the need for DOD support of basic science, the history of U.S. military support of science, the need for scientists to work for the defense of freedom, and, on the other hand, possible misapplications of science in armaments.			

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How Much Does the Defense Department Advance Science?

Arranged by D. DAVID TRIANTOS (*Technical Ed., Technical Info. Div., Naval Res. Lab., Washington, D.C.*)

Tue., 8 Jan. / Hilton / Cypress

9:00 a.m. Presiding: DAVID TRIANTOS

The National Value of DOD-Sponsored Research
GEORGE GAMOTA (*Dir. for Res., Office of the Under Secy. of Defense for Res. and Eng., Dept. of Defense, Washington, D.C.*)

DOD In-House Basic Research
ALAN BERMAN (*Dir. of Res., Naval Res. Lab., Washington, D.C.*)

History of DOD's Support of Science
EDWARD I. SALKOVITZ (*Dir., Material Sciences Div., Office of Naval Res., Arlington, Va.*)

A Broad View of DOD and Science
EDWARD TELLER (*Assoc. Dir. Emer., Univ. of Cal., Lawrence Livermore Lab., Livermore, Cal.*)

Science Sponsorship By the Department of Defense
GEORGE WALD (*Higgins Prof. of Biol. Emer., Biol. Labs., Harvard Univ.*)

ADVANCE DESCRIPTION OF THE SYMPOSIUM

Reproduced from the
"American Association
for the Advancement
of Science Annual
Meeting Program,
3-8 January 1980,
San Francisco,"
edited by
Arthur Herschman

DOD spends \$14 billion per year for R&D, which is nearly half of all government-sponsored R&D. In support of basic science and engineering the DOD budget is over \$1/2 billion in a national total of \$6 billion. A small fraction of the \$1/2 billion is given to in-house DOD laboratories, where science is pursued amidst a hardware-oriented R&D program. Almost all the rest goes to universities and some industrial laboratories. But DOD is now in fifth place in agency support of basic science, after a long history of being in first place. As an early example, the Army supported the Lewis and Clark expedition in 1804. More recently, DOD initiated research support for radar, computer sciences, integrated circuits, lasers, materials, and others. This large-scale support of research began during World War II. Support of academic research with federal funds first became highly fruitful under the leadership of the Office of Naval Research (ONR), formed in 1946. The Army, Air Force, and Defense Advanced Research Projects Agency (DARPA) followed the ONR pattern, with some variations. In fact, the ONR model was used in setting up non-DOD agencies like NSF and NASA. As an indication of DOD's attunement to the frontiers of science, a number of DOD-sponsored researchers have received Nobel prizes.

Thus DOD support of basic science and engineering to provide a base for future defense technology has advanced science in general. But answering the symposium title calls for answers to many other questions. Does the DOD's basic-research program oversupport research which is oriented to the solution of applied problems? Has DOD funding enhanced, or unduly influenced, academic research? Does the health of the DOD-university relationship need improvement? What is the status of the Mansfield amendment? Does military secrecy affect academic science? Would, for instance, changing the Naval Research Laboratory to the National Research Laboratory change the degree to which it advances science? What has DOD's drop to fifth place in agency support of basic science revealed about the extent to which DOD basic-science support is needed in advancing science and thereby ensuring national security? Finally, what is possible in the future?

[Sponsored by AAAS Section XI]

ADVANCE ABSTRACTS OF THE SPEECHES

Reproduced from the "Abstracts of Papers of the 146th National Meeting, 3-8 January 1980, San Francisco, California," edited by Arthur Herschman, American Association for the Advance of Science

How Much Does the Defense Department Advance Science?

Arranged by DAVID TRIANTOS (Naval Research Lab., Washington, D.C.)

Tues., 8 Jan. / Hilton / Cypress

9:00 a.m.-12:00 m.

The National Value of DoD-Sponsored Research GEORGE CANOTA (Department of Defense)

The American way of life has improved dramatically because of the many commercial applications - spin-offs - from research sponsored by the DoD. Our research programs date back to more than 175 years ago when the Army funded the first Government sponsored research program, the 1804 Lewis and Clark expedition that opened the West to Americans. Today our programs continue to take us to the fundamental limits of science and technology. We are exploring the far reaches of the cosmos as well as the deepest undersea environments. Medically and physically we are living better because of support of basic research by the DoD. For example, past DoD research led to cryopreservation of blood plasma and today we are on the way to developing a universal blood donor. In recent years some concerns have been expressed whether DoD support of science advances or hinders the process of discovery and innovation. Based on many decades of experience, we in DoD feel that our support of basic research strikingly and most emphatically advances science. There are many aspects to basic research. There exists no conflict between the researcher who is motivated by pure interest in science and the scientific program manager in a mission agency such as the DoD who is not only interested in science but also the applicability of his research to practical problems. Being aware of applications does not control nor disturb the aim of the investigator or the course of the research. Many examples from the past as well as from the present research program will be reviewed to illustrate this point.

DoD In-House Basic Research ALAN BERMAN (Naval Research Laboratory, Washington, DC)

The Department of Defense satisfies its needs for basic research through the twin mechanisms of contract research and the operation of in-house laboratories. The DoD In-House Laboratory Basic Research Program supplements the contract research program and provides for corporate memory and continuity of effort in areas which are of particular importance to DoD. In-house laboratories have the ability to maintain a sustained effort in areas of basic research to DoD but not necessarily at the cutting edge of science. For example, few universities today would be interested in maintaining a program of research in the area of cathode developments. Nevertheless, such research is necessary to DoD because of its continuing need for high powered thermionic tubes of new and specialized design. The record of DoD laboratories for performing forefront research that is equivalent to the best university research speaks for itself. At its best, the quality of research performed by in-house laboratories is equivalent to the quality of research at the best academic, national or industrial laboratories. The people who work at DoD laboratories are true members of the broad general scientific community. Because of the considerable career mobility of laboratory personnel, scientists migrate to and from industrial, academic, national and DoD laboratories. This continual cross-fertilization of the laboratories has contributed to the vitality and success of the DoD in-house effort.

History of DOD's Support of Science EDWARD SALKOVITZ (Office of Naval Research)

The Department of Defense and its predecessors going back to the early days of the Republic has sponsored research and development which has been deemed desirable for the security and growth of the nation. The explorations of Lewis and Clark into the Northwest for the Army and of Navy Lieutenant Stephens of the Yucatan and the mapping of coast and ocean currents in the 19th century are classics. Mention could be made of investigations initiated by the Navy of the causes of boiler explosions, which opened the way to better design and material selection. Michelson, a naval officer, made the most accurate measurements of the speed of light and with Morley conducted the famous experiment that bears their names. But the research was not by isolated individuals. Within government establishments Army arsenals and Navy gun factories began to address problems germane to defense. World War I may be said to have given a considerable impetus to chemical research, and WW II opened a new era for physics including electronics and most of the engineering disciplines. Today there is hardly a scientific or engineering discipline that has not assisted in the defense of the nation or has been assisted by DOD. Examples will be cited. In selection of research proposals, merit has been the prime decision factor. As a consequence DOD can point with pride to contractors who are Nobel Laureates, members of the academies, and prize winners of all sorts. It will be shown that the civilian sector has benefited immensely from such DOD-sponsored research.

A Broad View of DOD and Science EDWARD TELLER (University of California, Lawrence Livermore Laboratory)

In the field of physical science two recent outstanding examples of mutual positive interaction between DOD work and academic work is laser research and the space program. The latter could become even more fruitful if we exploited to the fullest extent the space shuttle program where our investments are sufficient to launch 70 shuttles per year. Opportunities abound for investigations on pure science, applied science and defense, all of which should be interacting. It is also highly desirable that this effort be pursued on an international basis where foreign experimenters should provide their own payload and possibly share in the expense of launchings. Secrecy has prevented truly fruitful cooperation between science and defense in the field of nuclear explosives. Apart from missed opportunities for science, secrecy actually has damaged our defense effort.

Science Sponsorship by the Department of Defense GEORGE WALD (Harvard University)

PROCEEDINGS OF AN AAAS SYMPOSIUM ON JANUARY 8, 1980: HOW MUCH DOES THE DEFENSE DEPARTMENT ADVANCE SCIENCE?

INTRODUCTORY COMMENTS AND INTRODUCTION OF GEORGE GAMOTA

David Triantos

Good morning. In this symposium the time schedule will be a half hour for each speaker, allowing a half hour for general discussion at the end. So I won't infringe on this time, I will be brief in setting up a framework in which to place this symposium. I will describe this framework in terms of my own situation. When I was a graduate student in physics at LSU, my major professor, Joe Reynolds, asked for and got funding from the Defense Department. In 1956 I left LSU and came to the Naval Research Laboratory to become a technical editor, working with scientists there to improve their research reports, which I am still doing. I chose the Naval Research Laboratory because I was impressed at LSU by articles that NRL scientists were then publishing in the Physical Review. Working with NRL scientists continues to be enjoyable and satisfying, and I see them doing outstanding work in the general advancement of almost all the physical sciences.

But I am sad that the mission of the Lab is to advance the physical sciences so they can be used in building a monstrous military machine. My hope is that there can someday be a worldwide cure to the mental cancer of them against us, and that we can learn that all people in this world are us. In that case, will the public keep the Lab going, doing as much or more in advancing science, but now with the mission that it will be used in building a better society controlled by all of us?

Thus in terms of my own experience and feeling you have a broad framework in which this symposium on science and DOD can be placed. Now I will let Dr. George Gamota introduce the symposium and present the first paper.

Dr. Gamota, as head of the Defense Department's research office, provides the Department-wide leadership and policy for the

Defense Department's 600-million-dollar basic-research program. He is a physicist and came to DOD 4 years ago from Bell Labs. At Bell he did research in quantum fluids and solids. Dr. Gamota.

WHY BASIC RESEARCH IN DOD?

George Gamota

It is a pleasure to be with you this morning and tell you something about the DOD basic-research program. I am delighted to be here because it provides me an opportunity to acquaint you with recent events of the Defense Department research community and it also provides me an opportunity to review for you the significance of past DOD science and engineering support and then to show you, in fact, how important that support has been to the nation.

With me today in this session we have a list of prominent scientists who will address various aspects of science in DOD. Dr. Alan Berman will speak after me of science in DOD laboratories, and Dr. Ed Salkovitz will review in detail some of the past scientific breakthroughs supported by the DOD. Lastly we have two eminent speakers from the private sector, Drs. Edward Teller and George Wald, who are to give their views on the subject of how much the DOD advances science.

Although I know that most of you are somewhat familiar with the DOD's basic-research program, let me briefly describe it to you, and in so doing, I believe that it will give us a better perspective and takeoff for our discussions to follow. Let me start, then, by identifying the four Defense agencies which have the research-contract responsibilities in DOD: the Army Research Office (ARO), the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), and the Defense Advanced Research Projects Agency, known to most of you as ARPA or DARPA. Together with the DOD laboratories, they support over

half a billion dollars worth of basic research in the U.S.

In the most simple terms, the DOD research program has two objectives: one is to team the Defense research community with the national effort, and the second is to develop the necessary scientific base for future technology in an orderly way. My personal and professional interest is in expanding basic research in as many technical areas as possible. To be sure, I, as a representative of the Defense Department, am also interested in a rapid military application of that technology. Let me stress, however, that military technological leadership goes hand in hand with commercial technological leadership and promotes, rather strongly, the development of that technology. The strength, vitality, and security of the U.S. rests in large measure on technology and its wise and rapid application. The prominent result is the establishment and maintenance of military forces ready to carry out whatever missions the nation may assign them.

In my opening remarks here, I can only barely begin to mention the advances that have come about through Defense-supported research. Dr. Salkovitz will provide you a larger sample. Let me cite just two examples: synthetic rubber and integrated circuits. Both technologies were spearheaded by the DOD for specific military applications. Yet, today, DOD is clearly only a small customer in the vast commercial markets that were created. With only few exceptions, it can be shown that almost any high-technology area, even though its purpose and function is civilian, may have some military use, and vice versa.

The synthetic-rubber case provides an interesting example. When events early in World War II limited our access to sources of rubber vital to the war effort, it was clearly a defense need that led to an accelerated research program directed toward synthetic alternatives. The success of this program, through the pioneering efforts of such eminent scientists as Carl Marvel and his colleagues at the University of Illinois, not only provided synthetic rubber for the war effort but revolutionized the rubber industry and led to enormous advances in the, then, embryonic field of polymer science. The subsequent benefits to science and technology are so pervasive as really to defy enumeration.

A more recent example is the DOD major program in high-speed integrated circuits. We, in DOD, are interested in high-speed integrated cir-

cuits because they are expected to provide the technology that will enable us to build electronics which will have real-time capability with artificial intelligence. However, once developed by the U.S. industry for DOD, these circuits will have an extended range of uses for the civilian sector and will provide the nation the technological boost in electronics development that it needs to overcome rather stiff competition from abroad.

This effort also comes on the heels of the ever-increasing concern that the U.S. is in danger of losing its technological leadership. This is in spite of the fact that technological innovation is very deeply rooted in America's tradition, from Benjamin Franklin and Thomas Edison to Bill Shockley and Jack Kilby. Industrial innovation in the past has played a major role in giving U.S. world leadership in the aerospace, chemical, and electronics industries. These are the same industries that continue to produce exportable products which provide strong, positive trade balances that often more than offset our large, negative trade balance in labor-intensive industries.

The concern for decreasing innovation in the U.S. has prompted President Carter a year ago to launch a major review of industrial innovation. There were two parts to this study: one was conducted by the government, headed by the Department of Commerce, and the other conducted by the private sector. While many recommendations came from these studies, one of the more important ones includes the recognition of the need for basic research and a need to better couple research in our universities with industry. It is noteworthy that the Office of Naval Research was singled out by the private sector as the ideal example of a government agency supporting research. In a most positive way they laud ONR for its great vision and effectiveness in its policies for supporting promising research.

Using another metric, that of Nobel prizes, one notes that within the last decade nearly 20 Americans who received the prize were supported by the DOD while doing their prize-winning work. Of course a much larger number would include those Nobel laureates who received support after they received their prize. But what is important in this is that over 20 were receiving support while they were doing their prize-winning work. This means they were not publicly very well noted at the time. Although most of the awards were for work in the physical sciences, two awards in economics, one in physiology, and one in medicine were included.

Due to my time constraint here, let me speak of three examples. Starting with some of the most recent Nobel laureates, we have Professor H.C. Brown of Purdue University, who received his prize in 1979 in chemistry for developing synthetic-chemistry methods. Over the years, Professor Brown was supported by ARO and ONR as well as other civilian agencies. During his Nobel-prize-winning work, Professor Brown specifically singled out ARO for its important contribution of support and its enlightened management policy. In fact, he felt so strongly about it that he wrote a letter to Time magazine to make sure that agencies which supported his work were given true credit for their enlightened attitude.

Another example is support of work which led to the 1978 Nobel prize in economics awarded to Professor H. Simon. This was for work concerned with developing new management ideas relevant to complex systems. ONR is credited for supporting this unorthodox, as it was called by some, work in its infancy. In physics there are many U.S. Nobel laureates who received DOD support. For example, Professors Bardeen, Cooper, and Schrieffer were supported by several DOD agencies including the Air Force while they did their work in developing the theory of superconductivity: the BCS theory.

I really don't have time to give you more examples, but clearly the DOD agencies have had and continue to have high-caliber technical people who have a good track record in selecting winners.

Some of the critics at large take DOD to task for steering science in the direction that somehow inhibits rather than enhances breakthroughs. If, by that charge, it is meant that DOD is selective in the choice of areas of research and exploits those areas which appear to have DOD utility, I must plead guilty to that charge. I must also add, however, that deleting DOD from the previous sentence would describe most of the researchers in the audience today and in the nation. We all look to jump on new ideas of opportunity, but basic research, by its very nature, would be unnecessary were it not for our poor record for making predictions of the important new areas or who will discover what and when. Therefore, in all honesty, I cannot single out any major basic-research effort in almost any field, particularly a new field, that could be categorically ruled out as potentially irrelevant to DOD. Our job is to follow the national trend and ensure that adequate

funding is provided in areas of potential interest to DOD, and, primarily, only limitations and the extent of other agency interests limit our scope. Those who say we steer science, I believe, give us credit for something that I wish we could do better, namely, predict the future. To be sure, we work very hard in applying basic-research ideas to defense needs, whether these ideas are in physics, physiology, economics, or medicine. In fact, that is the principal difference between program managers in the National Science Foundation and mission-oriented agencies like DOD: our program manager's primary role, besides supporting the best work possible, is to glean research results for our applications. It is not the researcher who is expected to find applications but the program manager.

Obviously, we also work very hard in trying to place our bets on the best people in their fields, and, in that way, try to stay at the forefront of science and engineering. As a further illustration of the point that I am endeavoring to make here, let me return to a case I mentioned earlier, that of Nobel laureate H.C. Brown. As you know, his classic researches on hydroboration have provided a powerful array of synthetic tools of inestimable value in broad aspects of organic, biological, and medicinal chemistry. Although DOD support of this work was originally influenced by our interest in high-energy fuels, to which hydroboration was peripherally related (in fact the program manager wrote, "high-energy fuels is a possible area of interest"), no DOD steering toward fuels was brought to bear when the work diverged into unexpected new fields of synthesis which culminated in the Nobel award. Our view was and is that the enrichment of our technology base through this work will ultimately be of greater value, and provide more exciting opportunities, than anything we might have visualized in our concern over fuels.

Let us continue to look at the record. For example, it can be said that DOD support of computer science and more importantly the creation of computer science as a field, has enhanced the U.S. technology by providing support at a needed and critical time. Today, it survives in a most healthy and independent fashion, having a tremendous impact in other areas: biology, meteorology, and, one of the most important fields in the private sector, medicine. Similarly support of materials science in the early sixties led to evolution of a healthy materials program in the U.S. If you will recall, in the aftermath of

the technological shock of sputnik, the U.S. attempted to counter the threat by a crash program in materials research, but, from government, only the DOD came up with a coherent and timely research program.

Let me summarize my point. The DOD basic-research philosophy is to support areas of science and engineering of interest to DOD emphasizing targets of opportunity. We do not, and in fact should not, limit our support to work with the only obvious application in mind, since few breakthroughs or revolutionary ideas can be preconceived. We, also, as part of the national research community, benefit from all new areas being pursued. Limiting our objectives in science would therefore be very counterproductive to our long-range goal of being technologically superior in the world. We would be very short-sighted if our program was directed only to the solution of today's military problems. Military utility may come from all areas of science and engineering. It is in our best interest to be involved, to follow them carefully, and to capitalize on their applicability to Defense's present or future needs.

The DOD has pioneered federal support of basic research, and it is our aim and goal to continue to ensure that this support will keep us technologically ahead. The part played by basic research in the essential and continuous modernization of military forces has not always been fully recognized. Just prior to World War II, military departments were doing almost no basic research and very little development. The Navy, for example, spent only 9 million dollars for all research and development in 1940. The result was that the defense force was not well informed of technical possibilities or fully aware of the engineering and scientific opportunities. These shortcomings were quickly and painfully recognized, and heroic efforts to overcome them were undertaken. These efforts resulted in the introduction of a variety of new technologies such as radar, nuclear reactions, homing torpedoes, jet aircraft, rockets, and missiles which not only changed the conduct of that war but also paved the way to our current technological leadership position in the world. After World War II, recognition of the contribution of research to military strength brought about a resolve to assure that DOD would thereafter make the fullest use of advances in science.

This was particularly true in electronics, where the progress has been so rapid as to term it

a technological revolution. Unknown to many, however, is that much of the initial progress was spearheaded by a 25-year-old DOD program called the Joint Services Electronics Program, or JSEP for short. The origin of JSEP dates back to 1945, when it was started as an Army-Navy program. The reason for its creation was to continue the close cooperation of the academic community in extending the nation's technological base in electronic sciences which was established during World War II. Such men as DuBridge at MIT, Terman at Harvard, and Rabi at Columbia who played key roles during the war in helping defend our country went back to universities after the war. The idea of JSEP grew up within the DOD and academia to help keep the channel of communication between them open and to continue to use their scientific ingenuity for defense. The premise was to build up large university graduate centers around skilled researchers who not only were working on the frontiers of science but were also cognizant of the defense needs of the nation. Initially there were three such individuals and correspondingly the three schools were involved in JSEP. Soon, however, the concept grew, and other programs with noted researchers were included. The hallmark and focal point, however, for all JSEP programs has always been and will continue to be a dedicated researcher who also has the rare talents to be able to perceive DOD needs and to manage an active ongoing research program. At present, in JSEP, we have 14 programs in 13 schools.

Today, electronic technology and its products provide us with a means of overcoming the numerical military superiority of other nations. The electronic option to military numerical strength is affordable, fairly reliable, and far more suited to present-day conditions. The electronic option needs to be even more affordable, more reliable, more available, and more understood by policy makers. Happily, we see in our military inventory an increasing number of electronic products. They include smart weapons that can find and precisely destroy targets, surveillance systems with a capability to detect and discriminate targets of interest from a world of clutter, aircraft with new aerodynamic capabilities achieved by replacing mechanical controls with digital-computers, and navigation systems capable of pinpointing locations with accuracy at impressively low costs. Most importantly, you only need to consider the prices of commercial hand-held calculators to

appreciate the phenomenal price reduction of most electronics for both military and commercial applications.

No single idea or development has made any of these items possible. Nevertheless, behind each system found in application there lies, in addition to much applied research a basic phenomenon without which even the system would not be possible.

The Department is proud of its relationships to the university community, a relationship that was strong and healthy up through the early sixties. In the mid-1960s and early 1970s, a number of factors caused a weakening of the working relationship that existed between the DOD and the scientific and engineering communities. We are now working to repair those relationships.

It is also clear that not only is the national effort in basic research vital to the Defense Department but that the Department must, itself, take part in the support of basic research. The matter is rendered even more urgent by the relative decline in the internal basic research conducted internally by industry and by the decrease of industrially supported research in the academic community. In some areas, activities of other agencies may remove much of the financial burden from the DOD (for example, much of the support of advances in medical science is funded by HEW). Even in these areas the DOD cannot abdicate all its responsibility and must have knowledgeable people who can apply those findings to defense needs.

Before I turn my attention to our current basic-research program, let me touch upon an important topic that has always — or at least since early 1970 — received wide attention in the academic community, namely, relevance and the Mansfield amendment. The Mansfield amendment is section 204 of public law 91.4, the Department of Defense appropriation authorization act of 1971, which is still in effect today. That section states, "None of the funds ... may be used to finance any research project or study unless such project or study has, in the opinion of the Secretary of Defense, a potential relationship to a military function or operation." There is absolutely nothing in the act which touches upon the loss of ability of the Defense Department to support basic research. The act only infers that as a mission agency DOD should support work that has a potential relationship to its mission. And, since its mission is very broad, only the

availability of funding and the level of interest of the agencies determines the spectrum of research support possible within the context of the DOD mission. Let me emphasize something that is very important, because as I travel through the country and talk to academic people the first question I get is, Well, hasn't the Mansfield amendment stopped you from supporting basic research? And the answer is, No, absolutely no. Clearly we have to look at the support as we choose projects, but, basically, we look for the best people possible and look for the new areas of opportunity.

To emphasize the importance of long-term basic research to DOD, several policy statements have been made recently. The President in his 23 March 1979 message to Congress, and then Secretary of Defense Harold Brown in a 30 May 1979 policy memorandum, restated DOD policy in this matter. Congress also, recently, spoke several times on this issue. For example, just recently, the House Armed Services Committee, in reviewing the fiscal 1980 budget, said, "The Committee supports the initiative of the under Secretary of Defense for Research and Engineering to increase funding for the basic-research program"

In the last part of my talk I want to touch upon the performers of basic research and mention some of the current program initiatives that we have started.

The basic-research program of the DOD is carried out by four groups of performers — universities, in-house laboratories, industry, and not-for-profit laboratories — each possessing special characteristics, each capable of making a distinctive contribution. In fiscal year 1979, 40 percent of the work was performed in universities and colleges, 40 percent was performed in DOD laboratories, and the remaining 20 percent was split between industry and nonprofit institutions.

The proper balance of DOD support for basic research among these groups of performers cannot be intelligently determined by any overall formula or arbitrary ratio. Continuing judgments must be made, based on merit, quality of proposals, scientific opportunity, availability of unique facilities or instrumentation, and most importantly, demonstrated excellence. Additionally, stability of the program, stability of the performing organization, and the appreciation that high-quality basic research is often a long-term endeavor should enter those judgments. For

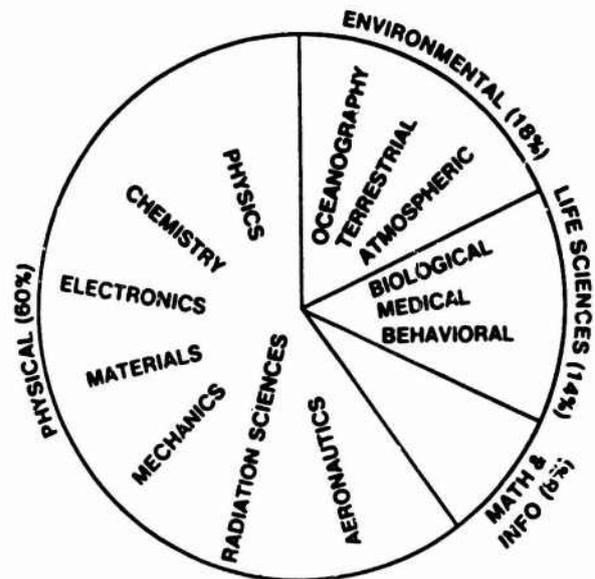
example, in early 1976 it was determined that the university fraction was too low, and an effort to reverse the imbalance was started. To minimize disruption of long-term research activities, the funding was not cut back from one sector and put in the other. It was done by emphasizing one sector over the other in the enhanced budget that was sought and obtained. For example, while overall basic research support increased by some 30 percent in the last 3 years, university support increased by nearly 70 percent.

A word now on program management. As I mentioned earlier, most of our contract program is administered by four DOD agencies: ARO, ONR, AFOSR, and DARPA. In addition, some DOD laboratories also let out contracts for support of research. Each agency uses its own system for reviewing proposals. While it might seem that these procedures lack uniformity, this system, I believe, enhances the chances of support of really novel ideas. Some agencies rely on the individual peer review, others obtain value judgments from committees, much like NIH, and still others internally review proposals. But, basically, there are four sources to which you can go to obtain support, and you are going to get four types of reviews.

While the overall program is heavily skewed toward the physical sciences, with physics, chemistry, electronics, and materials representing more than half the program, areas in social sciences, human factors, psychology, and medicine are also in the program. The pie chart shown by the viewgraph shows the breakout by specific areas. In this roughly 580 million dollars worth of work, we are talking about only the research program in DOD, and you should not confuse it with the much larger development program which gets involved with hardware.

To maximize innovation and flexibility, DOD has, in the last 3 years, increased substantially its support of block or cluster programs at universities. These are multidisciplinary, multi-investigator programs, somewhat similar to JSEP, which provide stable support for at least 3 years. To qualify for such a program, the principal investigator is asked to provide good management to the team, thus not only emphasizing government-university synergism but also providing a leadership base. Over 130 such programs exist today, at an average funding level of about 250,000 dollars for each program.

Our second major thrust is to increase the capital-equipment expenditures for our research-



ers. Equipment obsolescence and shortages are significantly affecting the ability of our researchers to take advantage of the newest and most advanced experimental techniques and, in some cases, to compete effectively with their foreign counterparts. While not earmarking any specific figure for equipment, we are initially pushing for a goal to enable the use of at least 10 percent of our contractual funding for equipment purchases. We hope that more substantial assistance in this area may be possible in the future.

A major effort has also been taken by DOD to improve our communications with the research community. Effective two-way communication is sometimes difficult on the large scale involved here, especially when multidisciplinary areas are involved; yet it is vital that we keep open as many channels as possible. A new way was started last summer when we initiated a series of 12 bi-monthly research topical reviews which are held at the National Academy of Sciences. These meetings, each of which is devoted to a specific discipline, are open to the public. Up to now we have had three such meetings: math and information science (last July), physics (September), and chemistry (November). The next two meetings are scheduled for February 4 and 5 on materials and April 15 and 16 on electronics. We have had excellent turnouts, with approximately 500 attendees at each meeting. Of the attendees, about half were from universities, a fourth from industry, and a fourth from government labs and agencies. Everybody is invited.

The last initiative that I wish to talk about is the procurement area. After a substantial 2-year effort we have established a DOD-wide uniform research contract. And, it's a one-page contract. If you can find another one-page document of this sort in the government, I'd like to see it. The use of this contract will reduce paperwork and red tape and will speed up the time between proposal offer and contract award. We have had excellent cooperation with the research community on this, and we will continue to strive to speed up and simplify the process even more. And, I think we can do it.

Finally my discussion and overview of the healthy interdependence between the DOD and the basic-research community would not be complete without acknowledging the strong bonds and cooperative relationships that exist between the DOD and other federal agencies concerned with the advancement of science. To cite just a few examples: DOD's pioneering research in radioastronomy was shared and subsequently taken up to a large degree by the National Science Foundation, as was the DOD initiative in developing synchrotron radiation sources. The government-wide effort in very-high-speed integrated circuits (VHSIC), which I mentioned earlier, involves not only DOD but the National Science Foundation and the National Bureau of Standards. DOD and NSF are currently discussing cooperative programs in support of national goals in computer science. And, lastly, DOD and DOE, the Energy Department, are jointly involved in planning the nation's program for developing synthetic fuels, with DOD slated to be the first user of many of these fuels.

With that I will end my discussion and thank you very much for this opportunity to present the views of the Department of Defense on this important matter of basic research in DOD.

INTRODUCTION OF ALAN BERMAN

David Triantos

The next speaker, Alan Berman, received his Ph.D. in physics from Columbia University in 1952. For the next 15 years in his career he remained at Columbia University, where he worked in the field of physical oceanography and underwater acoustics. In 1967 he was selected to become the Director of Research at the Naval Research Laboratory. At NRL he is responsible for the work of a staff of about 4000 people with

an R&D budget of about 250 million dollars per year. Dr. Berman.

DOD IN-HOUSE BASIC RESEARCH

Alan Berman

Thank you David. As Dr. Gamota has indicated, it has long been accepted within the Department of Defense that support of basic research is a necessary first step in a military hardware-acquisition process. The need for a vigorous basic-research program is also recognized as being necessary to prevent technological surprise and to develop entirely new capabilities.

Through the last 10 years substantial arguments have taken place relative to the issue of how the investment made by the Department of Defense in basic research would be administered. As George indicated, in the early seventies the management of basic research was dominated by a somewhat limited interpretation of the Mansfield amendment. Now the purpose of that amendment, as I understood it, was to force the Department of Defense to define the military relevance of all basic-research contracts. To some degree the objective of the amendment was to prevent the DOD from funding what was perceived to be undirected and unguided basic research. Partially as a result of the attitudes of the academic community during the Vietnamese war toward participation in DOD research and partially because of the Mansfield amendment the proportion of DOD basic research performed in in-house laboratories increased sharply during the 1970s. In the mid-1970s an attempt was made to reverse this process and to establish clear numerical limits to the amount of basic research which could be funded in DOD in-house laboratories. The reasons have never been made carefully clear, but the ratio of 30 percent in-house and 70 percent out-house was adopted as a kind of canonical ratio, and strenuous efforts were made to reduce the dependence of the DOD basic-research effort on its own in-house laboratories.

At the beginning of the current administration, the stated policy of reducing the level of budget of participation of in-house laboratories in DOD basic research was dropped. The view was enunciated that artificial ratios were not a good indicator of quality or productivity. About 2 years ago DOD announced a program to increase the funds invested in basic research by 10 percent a year in real dollars. A supporting component of

this program was that almost all growth would take place in the academic community. Current planning would hold the level of in-house laboratories more or less constant after the correction for inflation. The net effect of this policy will be to reduce the in-house participation in the basic research program from its current level, which is about 35 percent, to about 21 percent by fiscal year 1985.

On a personal basis I question the wisdom of this policy, as it relates to a significant reduction of the relative fraction of the DOD research effort performed by in-house laboratories. From a narrow corporate DOD standpoint, the maintenance and expansion of a strong basic-research program in its own in-house laboratories is justified by the need for a sustained and disciplined continuity of effort in areas of science that are of unique interest to the DOD. Finally, since the DOD laboratories are a uniquely effective set of organizations for the translation of the results of basic research into DOD systems, it is very much in DOD's interest to maintain the strength and intellectual vitality of these laboratories by giving priority to their needs.

Viewed in the broadest sense, the DOD satisfies its needs for basic research with the twin mechanism of a contract research program and the operation of in-house laboratories. The concept of the in-house-laboratory basic-research program is that it supplements the contractual research program, maintains the standards of excellence in the in-house laboratories that one achieves from scholarly research, provides intimate in-house awareness of the frontiers of science and technology, and ensures both a corporate memory and a continuity of effort in the areas which must be sustained by DOD because they are not of interest to a more general American community.

Since all in-house laboratories are also engaged in various phases of exploratory development and advanced developments, system acquisition, in-service introduction, and in-service maintenance and retrofit, they represent ideal organizations for the management and transfer of technology from basic research through technology to a product or system that satisfies some sort of need of the DOD. In a sense the DOD laboratories function very much like major-corporation research systems. The Bell Laboratories system, the General Electric system, and the RCA system are the sort of organizations that come to mind as

their analogs. Typically in such large corporate organizations one central laboratory is maintained that concentrates largely but not exclusively on the area of basic research. In the Bell system the corporate laboratory is in Murray Hill, New Jersey, GE's is in Schenectady, and in the U.S. Navy's system the in-house corporate research laboratory is the Naval Research Laboratory in Washington, D.C.

Now before we attempt to assess how a DOD laboratory contributes to science, we must first examine how it satisfies its mission in a more general sense. Even at a place like NRL, contributing to science is an important but not necessarily a primary function of the organization. The mission of the in-house laboratories is shown in the next viewgraph. Basically what we are seeing here is that these organizations are operated for the purpose of giving DOD a dedicated technical staff, which can provide knowledgeable technical assistance, advice, and consultation as appropriate. They are also required to be responsive to opportunities which may arise when scientific findings can be translated to technology, to maintain a research base, and to couple with and contribute to the general science and technology in this nation.

Now different DOD laboratories are responsible for different parts of this mission. No single DOD laboratory is responsible for all aspects of

MISSION OF DoD IN-HOUSE LABORATORIES

- TO PROVIDE A DEDICATED TECHNICAL STAFF WHICH GIVES CONTINUITY AND CORPORATE MEMORY TO THE SYSTEM'S ACQUISITION PROCESS.
- TO PROVIDE COMPETENT AND KNOWLEDGEABLE TECHNICAL ASSISTANCE IN THE DESIGN, DEVELOPMENT AND PROCUREMENT OF NEW MILITARY SYSTEMS—IN SHORT, TO MAKE THE MILITARY SERVICES SMART BUYERS.
- TO PROVIDE ADVICE AND CONSULTATION DURING THE INTRODUCTION OF NEW MILITARY SYSTEMS INTO SERVICE USE.
- TO BE RESPONSIVE TO THE OPPORTUNITIES TO PROVIDE IMPROVED MILITARY SYSTEM CAPABILITY PROVIDED BY NEW SCIENTIFIC DISCOVERIES AND BY NEW DEVELOPMENTS OF TECHNOLOGY.
- TO MAINTAIN A RESEARCH BASE IN THOSE AREAS OF SCIENCE AND TECHNOLOGY WHICH ARE ONLY OF INTEREST TO DoD.
- TO COUPLE WITH AND CONTRIBUTE TO THE GENERAL SCIENCE AND TECHNOLOGY EFFORT OF THE NATION.

that list. You will note on the list that only the last two requirements are predominantly oriented toward a contribution to science. Allowing for the fact that by and large the mission of contributing to science and the advance of the knowledge base of our country — our society — is a relatively minor component of the responsibilities of DOD laboratories, it is nevertheless interesting to consider the issue of how much DOD laboratories contribute to science.

The term "in-house DOD laboratory" is imprecisely defined. If you are able to get a computer printout of the DOD laboratories, you find a list of about 88 organizations. These range from relatively mammoth organizations such as the Naval Surface Weapons Laboratory, which I think has about 4900 people, at several geographically dispersed campuses, with an annual budget of about 350 million dollars, to tiny organizations such as the Arctic Research Laboratory, which has a permanent staff of three DOD employees, supplemented by some contract employees, with a relatively miniscule budget.

The population of the DOD laboratories is shown in the next viewgraph. I don't mean to get you involved in excessive numerology. The Navy's figure is somewhat inflated, because the Navy has a curious definition of a Laboratory. The Navy includes test-and-evaluation centers in the list of laboratories. By more conventional standards they would not be included. If one subtracts the test-and-evaluation centers, the Navy laboratory community is about 26,000 and is thus somewhat comparable to the Army and the Air Force. Whatever the numbers may be, taken in total the DOD laboratories represent a population of about 75,000: scientists, engineers, technicians, and support personnel. On any basis the DOD in-house effort must be accepted as one of the major science and technology efforts of this nation.

POPULATION OF DoD IN-HOUSE LABORATORIES

	MILITARY	CIVILIAN	TOTAL
ARMY	6465	21804	28269
NAVY	5737	33449	39186
AIR FORCE	11478	10472	21948

As you would expect, the staffing level, the quality, and the professional mix of personnel within the DOD laboratories varies greatly from laboratory to laboratory. Some organizations whose programs are largely oriented toward engineering development of military systems have staffs that are dominated by project-manager types, system engineers, and test technicians. Research laboratories such as NRL, which bear the burden of sustaining the in-house research program, have staffs predominantly dominated by scientists.

About 4 or 5 years ago I made a numerical comparison between the structure of the staff at NRL and the staffs of major corporate research laboratories such as Bell, GE, IBM, and RCA. Within a few percentage points all had the same ratio of personnel holding Ph.D.s to masters to bachelors degrees. None of the ratios differed very much when I compared those of NRL to those of the Bureau of Standards, the NASA laboratories, or the National Laboratories of the Department of Energy. At NRL about 40 percent of our professional staff are Ph.D.-level scientists. The remainder of the staff is relatively evenly distributed between people with masters and bachelors degrees. The non-Ph.D. component tends to encompass most of the engineering personnel.

Quoting numbers of our staff in our organization tends to be relatively unimpressive, for in the end it is the quality of the staff that counts. The point I wish to emphasize, and because of the limitations of time I will ask you to accept my word on faith, is that by any index or measure the quality of NRL's staff is very good. Typically, a young scientist comes to us after being selected as a National Academy of Science, National Research Council, postdoctoral fellow. After two years as an NRC postdoc, one year of additional service is required before the scientist receives the Civil Service equivalent of academic tenure. For a research scientist, promotion beyond the entry grade is carefully limited and is based on demonstrated performance, a strong record of publication, professional recognition by national or international professional societies, and finally by peer appraisal, a system very similar to that in a university. Among the factors which play a role in a young scientist's decision to come to NRL are the availability of excellent equipment, the choice of exciting problem areas, the possibility of full-time involvement in

research, and some idealism with regard to the necessity of maintaining a strong defense posture. Whether these factors will in the future still be adequate to offset the effect of inadequate government salaries and limited promotion opportunities remains to be seen.

In some sense one can tell much about the status of an institution by the collegial associations of its staff. Typically at NRL at any given time we have about 200 tenured university faculty members who are spending their sabbatical leaves with us or their summer vacations. Our list of visiting scholars generally includes personnel from 20 foreign countries. In addition to our visiting scholars and graduate students we have several hundred scientists from various institutions who work with us on a part-time and collaborate basis. I believe that at least half of our published papers were brought to us from other institutions.

Clearly among DOD in-house laboratories NRL is successfully pursuing that part of its mission statement which called upon it to couple with and contribute to the general science and technology effort of the nation. While we may be somewhat unique among these laboratories, the record of other DOD laboratories is equivalently impressive in this regard. Allowing for the fact that most DOD laboratories are actually engineering-and-development centers, credible research programs are pursued there by competent staffs. The laboratories all have active programs in collaboration with their academic and industrial colleagues. The collaboration of DOD in-house laboratories with the academic and industrial community goes significantly beyond the simple collegial association. In a very real sense, as George indicated, the in-house laboratories also act as funding agencies.

Next viewgraph. I hope you are not sitting there and trying to track all our figures, because

my figures and Dr. Gamota's never quite add up. In any case the total DOD basic-research funds for the year I took were about 475 million, and about 249 million was allocated to the in-house laboratories.

Next viewgraph. Within the in-house laboratories, only about 159 million was actually expended in-house, and another 90 million dollars went to contracts to universities, industrial laboratories, and not-for-profit organizations.

DISPOSITION OF FY 79 BASIC RESEARCH FUNDS AT DoD LABORATORIES

	TOTAL	IN-HOUSE	OUT-HOUSE
NAVY	61.3	64.7	16.6
ARMY	93.6	88.5	25.1
AIR FORCE	46.9	16.9	28.0
DARPA	27.3	7.3 ^E	20.0 ^E
	<u>249.1</u>	<u>159.4</u>	<u>89.7</u>

E - ESTIMATED

Again without being involved excessively with numerology, the point is that DOD laboratories actually spend about 160 million dollars a year of basic-research funds in-house and administer about 100 million dollars in contract research programs. This 100 million dollars incidentally is the basis of a remarkably fertile form of interacting between the DOD laboratories and the scientific community. In the process of developing sponsored programs, proposals are written, concepts are debated, and ideas are examined. The DOD laboratories certainly profit greatly from this process, and I believe the scientific community profits equally well.

On a personal basis, I joined the DOD laboratories after spending the first 15 years of my postdoctoral career in a university laboratory. I assumed my duties at the Naval Research Laboratory with considerable trepidation. I had concerns that the environment of a Civil Service laboratory would present problems in the area of classification and publication in the open literature. In most respects my concerns missed the point. While there are significant problems related to an in-house laboratory, they weren't the concerns I saw as an outsider.

DoD BASIC RESEARCH FUNDING FOR FY 79 (\$M)

	TOTAL	FUNDED TO LABORATORIES
NAVY	182.1	81.3
ARMY	116.2	83.6
AIR FORCE	164.9	48.3
DARPA	92.5	27.3
	<u>474.7</u>	<u>240.1</u>

Although NRL does not have a publish-or-perish syndrome, publication in the open literature is a necessary but not sufficient basis for scientific career advancement at NRL. Indeed one of the most distinguished awards that NRL bestows takes place at an annual publication-awards dinner which is held each year to recognize excellence in the quality of publications. Senior admirals and the Assistant Secretary of the Navy attend these dinners to give clear evidence of the Navy's interest in basic research and its publication in the open literature. In a typical year we present between 1600 and 2000 papers at professional-society meetings. In recent years, we've averaged somewhere around 800 to 900 articles in refereed scientific journals, books, or chapters of books. We also publish about 350 to 400 formal unclassified memorandums that reference both. Other DOD laboratories have equivalent records of publication in the open literature. For any given DOD laboratory the number of publications is proportional simply to the amount of basic-research funds available.

The commitment to basic research is not unique to the Navy but is found throughout DOD. As you probably know, the Secretary of Defense is a distinguished physicist. The Commanding General of the Air Force and the Secretary of the Air Force are physicists. Both have their doctorates and both at one time or another in their careers have been in charge of major research laboratories. Indeed Hans Mark, the present Secretary of the Air Force, was a coauthor of a publication in the Physical Review Letters as recently as 1979. He sent me a reprint of this article with a rather exuberant letter indicating that he didn't think the Secretary of the Navy, who is a lawyer by profession, could do things like that.

My point is that although DOD laboratories do a great deal of classified research, classification as an inhibition of publication rarely enters in at the basic-research level. Restriction of publication generally occurs only when a subsystem concept is being developed. In this sense it is very much like the process that occurs in an industrial laboratory. When research is applied and will add some possible corporate value, it is designated as proprietary, and publication is then restricted. Similarly the Department of Defense will restrict publications of certain applications in order to protect the DOD investment and to protect system effectiveness in a time of conflict. While one

could hope one could live in a world in which all information could be freely disseminated, unfortunately if we are realistic, we must anticipate conflict. It is thus necessary on occasion to restrict the dissemination of detailed developments arising from military research in much the same manner that commercial organizations protect the results of their research.

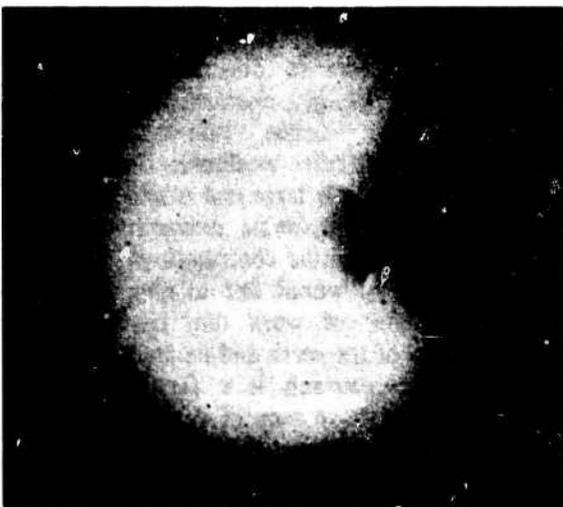
When I entered government service, I was concerned that the environment of the government laboratory would be intellectually limiting. Indeed the choice of the area of intellectual activity at DOD laboratories is somewhat restrained by the mission of the individual laboratories and the fact that the sponsor is the Department of the Defense. Certainly it is very difficult in this day and age to justify supporting work under DOD of topics such as why bees make honey. It may be possible, but I think it would be difficult. Scientists at organizations such as David Taylor Ship Research and Development Center do world-class basic research in the area of hydrodynamics. However, given their mission at the agency, it would be difficult for them to justify a program in agriculture research or something that is tangential to their mission. Within the areas that people are franchised to work at laboratories such as David Taylor and Walter Reed, they have a broad intellectual scope.

At NRL we can point proudly to our pioneering efforts in x-ray and gamma-ray astronomy. We can point to our basic efforts in meteorology, metallurgy, chemistry, oceanography, atmospheric science, numerical hydrodynamics, and molecular structure. The list of the areas we work in is large and would certainly do credit to any comparable university. Many examples of our scientific contributions could be brought forward. I would like to give just two that are examples of work that has changed mankind's view of the earth and its environment.

The next viewgraph is a famous picture many of you may have seen of a reentrant solar flare. This is a part of a spectroheliograph picture that shows the sun at 304 angstrom units, which is generated by doubly ionized helium in the sun. The picture was taken from the spectroheliograph on the Skylab satellite. It has completely revolutionized our concept of solar magnetic fields and solar flares. The next viewgraph, also an example obtained from space, was taken on the surface of the moon. The gold-plated device in the foreground is an NRL designed and constructed



extreme-ultraviolet camera. The next viewgraph, a photograph taken by the ultraviolet camera, shows the earth when you see only Lyman-alpha light, that is, light at 1216 angstrom units.



In the final photograph, taken in the light of atomic oxygen around 1300 angstroms, you can see for the first time an equatorial aurora around the earth. In my mind these results are revolutionary contributions of science to the human intellect. They change how we see the world in which we live, and they are profound.



My thesis up to this point has been that the DOD laboratories are in fact competent contributors to credible efforts of the U.S. scientific research community. They perform surprisingly well in a manner that benefits and increases the science base of the country generally, and they also serve the purpose of DOD, a mission-oriented agency.

There are, however, major problems with such laboratories, and these should be addressed in a serious way by any group that endeavors to consider the overall scientific health of the country. Considering the very large size of these organizations and the very significant fraction of the total scientific effort of the nation that they represent, I believe that I must admit that our society manages these organizations in a capricious and sometimes ill-considered manner. First and foremost, DOD in-house laboratories are Civil Service laboratories. As such they suffer from all the problems associated with trying to work within a very large bureaucracy. They also suffer very badly from this nation's institutionalized attitudes toward the Civil Service. As we all know, the tradition of American politics is to run for office on the ground that one will come to Washington, clean up the mess, straighten out the civil servants, cut down the bloated bureaucracy, and generally produce a lean and mean government which will not interfere in any way with anyone's life or business. It never happens, but the doctrine is reenunciated every 4 years.

The point is that for competent and dedicated scientists employed in DOD laboratories

this national attitude is devastating. The rules that are designed to attack people in regulatory agencies that annoy the public and politicians also attack scientists in federal and DOD laboratories. As a result, the personnel levels in DOD laboratories are cut without any relation to the mission of the laboratories, grades are arbitrarily frozen, and the number of senior positions available is rigidly circumscribed. As a result of Congressional action which has limited the number of billets of senior personnel, it is also impossible to promote a young Ph.D. beyond the entry grade. As a result the Department of Defense laboratories are suffering a tremendous attrition of their best and their youngest talent. They are in fact becoming training grounds for academia, for beltway bandits, and for industrial laboratories. Possibly in the long run this may be in the nation's interest. It is hard to say. However, if one accepts the premise that in-house laboratories are a necessary concomitant of the military's system acquisition process, then as American citizens we must have serious concerns about any process which affects the long-term continuity and stability of these national organizations.

In summary I would say the proposition that DOD laboratories contribute strongly and effectively to the scientific base of our country is unarguable. The record is clear; the record is strong. The laboratories have performed well under difficult circumstances not only in the area of basic science, which I have discussed here, but in the areas of applied science and engineering development. The laboratories are in my view an important national resource and should be recognized as such. They certainly should not be subject to the generalized abuse that our society seems to enjoy apportioning to anyone who works for the U.S. government. I believe that these laboratories must be supported as an important contributor to and component of the scientific community of the United States. Thank you.

INTRODUCTION OF EDWARD SALKOVITZ

David Triantos

The next speaker, Ed Salkovitz, got his Doctor of Science degree in physics at Carnegie Tech. He was at NRL from 1942 to 1960, where he worked benchside and organized the Metal Physics Branch. He was at ONR from 1960 to 1964 as Head of the Metallurgy Branch. He was at

DARPA in 1964 and 1965 as Head of the Materials Sciences Division. From 1965 to 1973 he was Chairman of the Metallurgy and Material Engineering Department at the University of Pittsburgh. While he was there, he taught a seminar on science and public policy. During 1970, 1971, and 1972 he was Chief Scientist at the London Branch of ONR. From 1973 he has been at ONR again, as Director of Material Sciences. Dr. Salkovitz.

EVOLUTION OF DOD SUPPORT OF SCIENCE

Edward Salkovitz

I will begin with a sentence in Dr. Gamota's talk: "It is clear that not only is a national effort in basic research vital to the Defense Department but also that the Department must itself also take part in support of basic research." In this talk I hope to sketch the evolution of DOD support of research and to show its considerable positive impact on the civilian sector. Before I go any further, I should acknowledge that much of my early material comes from Dupree's classic work *Science in the Federal Government*.

Using that source, let me start with the beginning of the Republic. As we know, there were uniquely gifted people in the Colonies, interested in science, or natural philosophy as it was called, usually as an avocation. Among these were some who wished to develop a national science policy. Specifically, they petitioned Congress for financial aid to erect a national chemical laboratory, to develop a program to "study the fundamental law that rules over the solar system," and to find longitude by lunar observations. Unfortunately the committee of the House of Representatives reported that the Constitution appeared to have limited the power of Congress to grant patents only.

Leaving the colonial period, we find Jefferson sending out the Lewis and Clark expedition after requesting funds from the War Department to cover salaries and rations. The Congress opened the public purse, but only after resorting to authority granted by the commerce clause of the Constitution. Here, by using Army funds, Congress blessed scientific expeditions conducted by the military organization. This was a very important step, because there followed a series of expeditions into the west. As an expedition, the Lewis and Clark expedition was a magnificent

success. Adequate plans, however, had not been made to receive the information or the specimens that had been gathered, so that the expedition did not contribute much to science.

Meanwhile Jefferson reversed himself on military academies, which he had opposed for many many years, by creating the Corps of Engineers, which were stationed at West Point and which he directed "shall constitute a military academy." During this Jeffersonian period John C. Calhoun, noted for later roles in life, reorganized the War Department. He sent Major S.H. Long to explore the Platte River, to search for headwaters of the Red River, and return via the Arkansas. The importance of Long's expedition was that it included not only a military corps but also a scientific corps. So accompanying Long were a botanist, a zoologist, an assistant natural scientist, etc. Upon the return of the expedition, collections were classified and the results were published, in total contrast to what had happened with the Lewis and Clark expedition.

Calhoun's first surgeon general of the Army, Joseph Lowell, believed that some correlation existed between disease and weather. He instructed his doctors at various military posts to gather weather data for several years. This was the first time that such a study had been done on such a gross scale. Meanwhile Calhoun put sufficient life into West Point to give it the characteristics of a college. There is no question that it was West Point that gave impetus to the civil engineering in this country. West Point graduates surveyed for the railroads, canals, and roads. Later we will see that the Army had a tremendous influence on public health.

Turning now to President John Quincy Adams, in his first annual message to Congress he advocated a national observatory and a naval academy "for the formation of scientific and accomplished officers." Again, regrettably, this suggestion did not gain much support.

Moving rapidly along, we come into the Jackson administration, and we find that that decade was a unique one. It was the decade in which Darwin's voyage of the *Beagle* took place. It was also the decade of the Antarctic explorations of Sir James Clark Ross, for whom the Ross Ice Shelf was named. Just as we are aware now of how sputnik spurred our explorations into space, so these explorations by others spurred Americans to enter into the field of scientific exploration. In May 1836 President Jackson

signed a bill authorizing the so-called United States Explorer Expedition, to be funded largely with Navy money. The results of that expedition, which was led by a naval lieutenant, Charles Wilkes, came from Latin America, the Antarctic, the central Pacific islands, and the western coast of North America and touched just about every natural and physical science of the times. The seeds and live plants which were brought back were the basis for the U.S. Botanic Gardens in Washington, D.C. Some of the executed survey charts were sufficiently well done that they could be used in World War II.

Returning to Calhoun, it was under his guidance that there was created a Corps of Topographical Engineers which was responsible for a very comprehensive plan for canals between the Chesapeake and the Ohio and along the Atlantic seaboard, and also for making the Mississippi and Ohio Rivers navigable. The Corps even worked on the national road which ran from the east coast to the west.

The specimens brought back from their expeditions converted the Smithsonian into a true museum. In effect these expeditions were the graduate schools for a whole generation of naturalists. In the same period naval expeditions explored Central America, the Amazon, and even the Dead Sea, collecting scientific data and making topographical and hydrographic observations. An important naval astronomical expedition was sent to Chile whose purpose was to determine the sun's parallax by observations of Venus and Mars from stations in the Northern and Southern Hemispheres. The expedition's party spent 4 years collecting data on earthquakes, weather, magnetism, and natural history as well as cataloging the stars as seen from the Southern Hemisphere. Commodore Perry's visit to Japan is well known. Shortly after that visit the Navy sent its North Pole Exploring Expedition to Asiatic waters with the instruction that the expedition was "not for conquest but for discovery."

Turning to another aspect, Lieutenant Matthew Maury, the commander of the Navy's depot of charts and instruments, conceived the idea of producing weather and current charts and sailing aids from weather and oceanographic data. He set up a global reporting system for ships and introduced a monthly tidal chart, an aid that remains in use today. Maury published the first bathymetric chart of the North Atlantic, and his studies of the ocean bottom contributed greatly to

the success of the laying of the first trans-Atlantic cable. In addition the first textbook on oceanography was written by Maury.

From what I have said so far, you can detect that the government's interest in research reflected the needs of commerce and western expansion. As a result the sciences that were encouraged were the collecting and exploring type. Laboratory science was of little interest to the government.

Coming up to the Civil War, we know that the Navy faced it with new technological background. There was John Ericsson's iron-sided ship Monitor, for example. And a Bureau of Steam Engineering was established in 1862. By the time the Civil War broke out a hastily built steam Navy successfully blockaded the South. The year 1862 also saw the establishment of the Navy Permanent Commission, as it was called, "to which all subjects of a scientific character on which government may require information may be referred, and which shall have authority to call in associates to aid in their investigations and inquiries" (sometimes called consultants). The commission met frequently throughout the war and screened hundreds of unsolicited inventions. It had no budget and was not a research organization. But what is important about the commission was the three men it consisted of: Admiral Davis, Dr. Joseph Henry, and Alexander Bache, a descendant of Benjamin Franklin. These three were largely responsible for the formation of the National Academy of Sciences. Moreover the Academy's first report dealt with the practical problem of calibrating compasses aboard ships equipped with iron smokestacks.

As for the War Department, in 1812 it established the Ordnance Department, which conducted research in support of its procurement function. Unfortunately the acceptance of its findings was so slow that after the Civil War the War Department was criticized for use of outdated arms and inadequate ordnance-testing facilities. Therefore the Department responded by establishing in 1873 the Metallurgical Research Establishment, at the Watertown Arsenal, outside of Boston, which developed an international reputation and was responsible for the best metallurgical work in this country for some time.

With the close of the Civil War there was a general decline in interest of science within the military, but there were particular exceptions. As one example the Naval Observatory began a

world-recognized program of fundamental research in astronomy. Perhaps more importantly, it became the training ground of young scientists in a variety of fields. In the decades following the Civil War the Army Medical Museum and Laboratory had illustrious careers. The museum became a center for experimentation in methods and equipment for photomicrography, particularly of microorganisms. The story of the conquest of yellow fever is quite well known. The Army medical school, the museum, and the laboratory all provided headquarters for the onslaught on this horrible disease. They brought the science of bacteriology to a high point in this country and contributed greatly to the concept of public health. The relationship between hookworm and anemia was established, as was a practical treatment. Later the use of anhydrous chlorine to purify water was demonstrated. As a result of the many distinguished accomplishments of the Army Medical Corps, World War I was the first major war in which the mortality from communicable diseases was less than that due to wounds.

Approaching the twentieth century, there was little support of research by either the Army or the Navy, although during the Spanish-American War an Army-Navy board investigated Langley's experiments to determine the possibilities of developing a large man-carrying flying machine. The War Department allotted Langley 50 thousand dollars. Unfortunately in December 1903 Langley's plane crashed into the Potomac, putting an end to his aeronautical but not scientific career. Nine days later occurred the Wright brothers' successful flight. Communication also received attention during this period. In particular, radio communication was seen as a potentially valuable asset to the Navy, so that in 1908 it established the Radio Telegraphic Laboratory and gave contracts, including one to Lee De Forest, one of the pioneers in television.

At the outbreak of World War I, recalling the Permanent Commission of the Civil War, a naval consulting board was appointed with Thomas Edison as its chairman. During the war 110 thousand suggestions from patriotic inventors were culled. Only one was deemed worth carrying through to production! I think this is a clear condemnation of this random answer to the war-time needs. Although World War I did lead to the formation of the National Research Council to enable the Academy to make its contributions,

government funds were not made available. However, many private foundations came to the rescue. Soon physicists from universities and industry were actively engaged in developing listening devices for determining the bearings to submarines. The German use of toxic gases prompted General Pershing to cable for extensive investigation of these gases. Chemists were hired to augment the Bureau of Mines personnel who had some experience with noxious gases that had been the cause of a series of coal-mine disasters. In addition chemists were brought in to synthesize materials and to uncover the secrets of high-quality glass, which up to that point had not been produced in this country.

Between World War I and World War II there was little activity on the basic-research scene within the Department of the Navy, with the exception of the creation of the Naval Research Laboratory. With the coming of World War II, basic sciences in universities were mobilized in strikingly effective ways to support the wartime objectives, especially under the guidance of Dr. Vannevar Bush.

Let's turn to July 1941. Secretary of the Navy Frank Knox now established within the Office of the Secretary the Navy Research and Development Board, whose chairman was designated the Coordinator of Research. It was the latter's duty to advise the Secretary on matters of naval research. Professor J.C. Hunsaker, the chairman of the National Advisory Committee for Aeronautics, agreed to serve as the coordinator on an interim basis. He selected a small staff consisting of two regular Navy officers and four young Naval Reserve officers who had technical backgrounds. He called them his bird dogs. He gave them valuable training in research planning and assigned them highly responsible tasks, thereby providing a combination of confidence and morale which showed in future accomplishments. It was this small group of bird dogs who conceived the idea of the Office of Naval Research and who sold it to the Navy, the Executive, and the Congress. The concern that the research structure established by Dr. Bush would disappear after the war had considerable influence on these men. They concluded that after the war the Navy had to supplement its own in-house research with basic research in the universities in order to maintain a modern navy. Next was established the Office of Research and Inventions (ORI), whose structure and functions would

eventually characterize ONR. The chief of ORI was assigned the responsibility for coordinating research information and for advising the Secretary of the Navy on naval research. He was also given the authority to initiate research and was provided specific authority "to execute, on behalf of the United States, contracts." Here for the first time in print was the authority to put out contracts, providing a new dimension to government support of research.

In some circles there were doubts about whether the Secretary of the Navy had the authority to do all this. Upon request, President Truman issued an executive order sanctioning Secretary Forrestal's directive, under what were known as the first War Power Acts. Important questions concerned the legality of transferring funds and protecting the concept of longevity of basic research. The Secretary was concerned that no one would finish a piece of research with a 1-year contract. What do you do about the second year? The solution was specific legislation authorizing the activity and on which basic research could make a claim before the relevant Congressional appropriations subcommittees. On 27 March 1946, Congressman Carl Vinson, who was then the chairman of the House Committee on Naval Affairs, introduced a bill to establish the Office of Naval Research. After initial amending proceedings were completed, the House and the Senate passed the bill, and President Truman signed Public Law 588 on 1 August 1946, just a few months after the initial effort by Carl Vinson. The mission assigned to ONR by the bill is "to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval powers and the preservation of national security."

In the Army most laboratories were conducting research in-house, augmenting their work by individual contracts. The Chief of Army Ordnance centralized his contract research program in 1951 at Durham, North Carolina. In 1961 this office became the Army Research Office. The Air Force designated its Office of Scientific Research (AFOSR) to be the contracting agent. It would be impossible to refer to all of the important fields which were and are greatly influenced by the creation of these agencies. In my closing minutes I will show some favoritisms, since it may be noted that I am at ONR and that my field of interest is materials.

The decade which followed the birth of ONR witnessed the genesis and growth of several new fields. Metallurgy, for example, was transformed from a traditionally chemically-oriented into a physics-oriented discipline. There is now a relatively good balance between the two kinds of metallurgy. Advanced solid-state physics produced an impact upon metallurgical thinking, research, techniques, and graduate curricula.

Within the period of the mid and late fifties better materials became the common need for jet aircraft, for electronic devices, for nuclear reactors, and for a host of other things. New classes of materials and new concepts of design were required not only within the military sector but also in the advancing civilian sector. The needs advanced faster than the accumulation of the October 1970 successful Soviet sputnik caused a revolution in U.S. science and technology.

Of great concern was the limited number of graduate students in materials related disciplines and the inadequate if not obsolete university physical plants, including research equipment. It was clear that electron microscopes, ultrahigh vacuum systems, and a variety of spectrographs were to play an important role in developing solid-state sciences including materials. The existing agencies found that with their policy of funding individual professors primarily, they were unable to supply such equipment without severe impact on their whole budgeting process. This was true for all the agencies, not only DOD agencies.

Of the federal agencies, it was the Department of Defense which addressed this situation quickly and clearly: first by creating the interdisciplinary laboratories, the so-called IDL laboratories, within the recently created Advanced Research Projects Agency, and second by funding a very large general-equipment program administered by the three services. By this means a new concept was again created in government support. And funding of materials basic research quickly doubled. Further, the DOD now undertook major university building construction for research and education. Later, in 1965, seeking to develop a closer relationship between university and DOD materials needs, the Advanced Research Projects Agency initiated a series of coupling programs, which Dr. Gamota mentioned.

I will just comment, to bring us up to date, that Dr. Gamota has indicated to some extent the newer things we are doing. This emphasizes that

DOD agencies are not static in their philosophy on support of research. There is considerable flexibility. Not only are new modes of funding coming to the fore, but there is a strong emphasis in all three services to giving particular attention to the needs of the young faculty members.

In summary, we have seen historically that DOD support developed from early ad hoc sponsorship of expeditions and specimen gathering, but with no true science policy as the backdrop. As technology made its imprint, testing and standardization became important. But it was only with the close of World War II that the necessity of research sponsorship by DOD was accepted. Since then there has scarcely been a scientific discipline that has not benefited. The standards set have been high, and, contrary to early concern, there has not been government interference. As a result DOD-supported research is documented in leading scientific and technical journals, often to appear as textbook material or standard reference tables.

I will finish by listing a few of the accomplishments. My colleagues can extend the list several times without repeating items which I have listed. Before I read the list, I want to point out that as in all research the products may be of two kinds. In one case one comes up with a better material or a new technique or a more reliable number. In the other, concepts are developed and models for phenomena are generated, which in turn may lead to predictive capability. The DOD programs produce both types of products. The list of some areas of achievement is as follows:

- All aspects of cryogenics, making it possible to do very important physics, chemistry, metallurgy, and biology not previously possible.
- Freeze preservation of blood. Continued research is leading toward a universal blood donor through enzyme modification of the red blood cell membrane.
- Basics of atomic and molecular physics, leading to precision clocks.
- Improved navigational tools and systems.

- Computers, computational methods, artificial intelligence, computer-aided instruction, and communications.
- All aspects of oceanography.
- Early balloon studies of the upper atmosphere, which led to better radio transmission and reception.
- Principles of radar and its continued development.
- Space physics.
- Concepts and practices in wound healing, especially burns.
- Theories of imperfections in solids.
- Principles of fracture mechanics, failure criteria, and strengthening mechanisms.
- Superior alloys. They range over the spectrum from steels for cryogenic applications to high-temperature alloys for jet turbines.
- New classes of materials: a variety of composites (now found in sports gear) called "glassy metals" (amorphous).
- Corrosion control in a variety of environments.
- Magnetism. For many years the Navy was the primary sponsor which led to improvements in a variety of new magnetic materials, the ferrites and devices. Later the Air Force entered the picture, sponsoring the National Magnet Laboratory at MIT.
- Radiation dosimeters.
- High-energy-density batteries.
- New chemistries (such as transition metals, boron, fluorine, and free radicals).

- Spline-function mathematics.
- Processing and evaluation of materials.
- Substitutes for critically scarce materials.

INTRODUCTION OF EDWARD TELLER

David Triantos

In the abstracts of papers for this symposium there is an abstract by Dr. Edward Teller. However, in view of present events, he has decided to vary his presentation from that abstract. Dr. Teller.

HOW WE MUST USE SCIENCE FOR THE DEFENSE OF FREEDOM

Edward Teller

Ladies and gentlemen. Between the time this symposium was planned and the present some tragic and ominous events have occurred. This makes it necessary, of course, to speak to you in a very different way. I am reminded of a difficult time in my life, the time preceding the entry of the United States in the second World War. I have been familiar from the very beginning with a phenomenon of fission and the consequences that are apt to follow. Because of the deep interest of some of my friends, I was involved in the earliest attempts to initiate fission research. But I was a scientist, not interested in arms or politics. I knew how dangerous Hitler was and how much more dangerous he would become. Yet I had not managed to decide and tear myself loose from my chosen purpose in life and work on pure science. I know to the minute when I made that decision, and I want to share it with you.

On the day after Hitler invaded Belgium and Holland there was a huge Pan-American conference, to which I did not want to go, because it obviously would have had little scientific interest. But I went when I heard that Roosevelt, who I never listened to before, was going to address the question of Hitler's latest invasion. Toward the end of his address Roosevelt said, "You scientists are accused of having invented dreadful means of destruction. But I am telling you that if scientists in the free countries will not work on weapons,

freedom will cease to exist." I had an unreasonable feeling that Roosevelt, who of course did not know that I existed, was talking to me. I had been there when Einstein signed a famous letter to Roosevelt. I had good information that on receipt of the letter Roosevelt went immediately into action. I knew that Roosevelt was aware of the new and more terrible bombs we were discussing. My mind was made up, and it has not changed since.

Today in Iran the normal mode of diplomatic communications has been abolished. Today in Afghanistan the Soviets continue what they have started in Hungary and in Czechoslovakia. I have listened here with pleasure to the splendid talks of my colleagues and their description of remarkable scientific accomplishments. Yet in spite of this the Soviets today are ahead of us in the military field, not only quantitatively, but, what is truly scandalous, qualitatively. Our scientists have been too confident about American technological know-how. They have been ignorant of the danger in the academic circles, and they have only been partly aware of the danger even in the Defense laboratories.

What has already happened is a dreadful warning. What may come next, no one knows. There is a possibility that the Soviets, who are so active now in the Middle East, will soon take over the resources of the Middle East, that they will control the oil spigot, that we and, even more, Europe and Japan and, most of all, the third world will have to do the Kremlin's bidding. That we are approaching a time of danger, whether for the detailed reason I mentioned or not, has become very clear. President Carter has acknowledged that, in the last short period, he has learned more about the Soviets than in his whole presidency and that what he has learned is not good.

I want to make a clear and simple statement. I am completely opposed to an arms race. I am completely opposed to spending more and more money on military objects already known to us. That way, we are not going to improve the safety of the world, we are not going to defend freedom, we are not going to prevent a third world war.

What we need is a cooperation of the scientists as strong, and I think stronger, more effective, than it was before the Second World War.

The Second World War produced miracles of science. A byproduct of the nuclear activity was ample availability of radioactive substances like technetium and thallium, which has been used recently on me after my heart attack, to find out whether open-heart surgery is needed or not. As a result of wartime development, radio astronomy and marvelous new knowledge about the universe has become available. Accelerated by the second World War, we went out into space, we reached the moon, and we shall reach beyond.

These are magnificent achievements. None of it justifies the horrors of a war, of any war. But without scientific development, we will have only the choice between the stifling influence of a totalitarian world that controls technology or we have the choice of science and technology in the hand of those who want peace.

For that purpose we must work on technology. Now let me put down the first requirement for that work on technology. It is a requirement that tragically has not been fulfilled. Science does not tolerate secrecy. We have kept too many things secret, and this didn't help science. Furthermore, contrary to generally accepted claims, it did not help national security. As long as we knew more than the Soviets about technology in warfare, there might have been a justification of secrecy. The Soviets today know all of our secrets and many which we have not yet discovered. For us secrecy today is nonsense.

Let me give you an example, Secrecy in nuclear weapons was the strongest of all secrets. The Soviets are today fivefold ahead of us in the throw weight of their nuclear-tipped rockets, and I have reason to believe they are qualitatively ahead of us also, only I cannot present the evidence. In electronics, where there are practically no secrets, we are ahead of the world. And that is a field that indeed may come to our rescue in today's critical situation, if we fully and properly apply it to defense purposes.

The fact that our scientists are ignorant of the great danger, with the very existence of the United States in the balance, is due to secrecy, because secrecy did not allow us to let the people know, to let the scientists know, how great the danger is.

I would like to go a little further. I would like to go a lot further. But I can't. Not only am I limited by secrecy, I am limited by my own lack of imagination. Soon I will be 72 years old. It is

the young people who have the ideas. It is the young people who have the potentiality to save the United States and to save freedom. The solution is not in ever more weapons.

The solution is the development of unpredictable, unimagined technology. And this should be pursued, not just in the United States, it should be pursued for the common purpose of the survival of freedom by the collaboration of all free countries. It should be pursued without the shackles of secrecy. Let the Soviets know, and let everyone know, what we are doing, except for the little details called know-how, which are essentially incommunicable. The greatest secret I ever kept was quantum mechanics, which I tried to explain to my students, and I never quite succeeded. What we might lose by the Soviets knowing what we are doing, we will gain back a hundredfold by ourselves willingly and freely being able to move faster in collaboration with all of the free world.

Now I want to tell you what I said I cannot tell you. My imagination is finite, but such as it is, I want to tell you what are the things that we should be working on, knowing full well that the young people will come with other ideas and with better ideas. Yes, we should work on atomic weapons; we haven't done enough. More importantly we should and we can work on defense against atomic weapons. Beam weapons, at least at a short range (without some of the exaggerations that have been current in the literature), can do a lot to destroy incoming missiles at a distance of a few miles. Beams, electromagnetic or charged, might become most important.

I mentioned electronics. It is invaluable. What we could do is develop remotely piloted vehicles. Take out the pilot from the airplane. Take out the soldiers from the tanks. Take out the sailors from the ships. These weapons will become smaller, cheaper, more numerous, and more expendable. With our microelectronics we cannot merely make small watches and small computing equipment, we can make sensors that can gather all the information that is needed in a plane, in a tank, in a ship, in a submarine. That information through multiple links can be brought back so that more remote people more calmly and with more reason can make the needed human decisions. And these weapons can serve for reconnaissance, can help to prevent war, can be used for attack or for defense.

Everything that a well-programmed mind might do, a machine, a computer, can do better. And an average military mind needs to be programmed. In almost all cases it can and should be replaced by a computer. The best military minds belong in the command posts where information is received and where decisions originate.

We should not vote 9 percent more in real currency for the Department of Defense. Excuse me gentlemen, it is not the science departments I want to cut. I like to think first and then act. Today this means that the scientist must begin to act. How? According to what principles? Let me leave this to the end and let me mention to you two more ideas.

We are on the border of modifying weather. And when we have learned how to do that, we will have done something terrible; we will have lost our last safe topic of conversation. Weather modification should be used peacefully, should be used to decrease the reasons for war, should be used for collaboration between nations, because weather does not know international boundaries. But in the last analysis, whatever can be used for war can be used for peace, and whatever can be used for peace can be used for war. There are no boundaries between basic and applied research. Neither are there boundaries between peaceful and military inventions.

The last topic and the most important. By the year 2000, probably there will be 7 billion people in the world. Our numbers will not increase without limit. People are changing, but they cannot change their habits quickly. Before the year 2000, countless millions will starve, and the starvation will give rise to despair, quite possibly to war. The greatest storehouse of wealth that we must utilize are the oceans, and they are properly utilized by scientific means, and by scientific means executed by international agreement. At the moment there is no hope that the whole world, including the totalitarians, should agree. We must start, alone if need be and, if ever possible, together with our friends. Then the activity will and has to spread.

If the men in the Kremlin can see that there is vitality in the West, they will never attack it. The best two sides of vitality are science and cooperation. And these will not flourish without progress.

Today there is no Roosevelt who will say to the young scientists what a great president said to

me in the tragic year of 1940. The 1980s need not become tragic. The third world war and the subjugation of the world by totalitarian forces can yet be avoided and avoided peacefully. It cannot be done without power in the hands of those who love peace more than power.

There can be no question where the power, where the science, where the invention must come from in order that peace be preserved and in order that freedom shall continue. The choice is not between being Red or dead; the choice is between being free and alive or living in a world in which there is no freedom and there is continuing destruction.

Modern weapons will never destroy human kind. They will never destroy technology. They may, for many years to come, destroy freedom of thought. To my mind, freedom and science must not be and cannot be separated. Thank you.

INTRODUCTION OF GEORGE WALD

David Triantos

The next speaker will be Professor George Wald.

DANGERS OF USING SCIENCE FOR THE ARMS BUSINESS IN A CORPORATE STATE

George Wald

Well, Edward Teller has introduced us to his nightmare world. For a moment let us come back to the reasonable spirit of the early parts of this session. I too was impressed with the excellence, the intelligence, and the human concerns of the previous speakers. But now I think we have been projected into the insane world that unfortunately has a more pressing reality for all of us than that world of reason that the previous speakers so much emphasized.

Teller sees a new, tragic, and ominous event. I think he's talking about Afghanistan. But as it happens, although I don't work at it, I have in a folder a few things that Teller has told us before. I have not done any extensive research I assure you, I have other things to do, but I think the earliest clipping I happened to save is 1967, and once again Teller was saying that the Soviet Union was ahead quantitatively and qualitatively.

Fortunately I know other people whose lives are deeply involved with armaments. I want to

say that to my best knowledge the United States has been ahead roughly 5 years from the very beginning of the arms race and is 5 years ahead now in the technology of armaments. This whole situation makes me uncomfortable, because it contains the implication that perhaps it is we who are leading the arms race. I don't know to what degree that is true. I want to tell you I have no confidence whatsoever in the judgment and peaceful intentions of the Soviet government. Nevertheless we were 5 years ahead at the beginning, and I think we are 5 years ahead now.

You know, it's curious, I argue sometimes with good friends, physicists, who are starry eyed about coming into radio communication with what they call more advanced technological societies in outer space, but they have been listening for a generation now without hearing anything meaningful. The thought is spreading: perhaps there are no more-developed technological societies in outer space. Perhaps they eliminate themselves as they reach our stage as we are threatening to do. Teller talks about those improved nuclear weapons preserving free thought and science. But one needs people to think — people to make science. And what we really worry about, of course, is that the present stockpiles of nuclear weapons, if used, are enough to wipe out humanity.

So one needs to ask the question, What are the chances they'll be used?, because I find as I go about that there are numbers of people with the comfortable thought, It's all a game; nobody's going to use that stuff. So I want to point out to you that World Wars I and II were started by the nations that ended up losing them. Just think that over a bit. The nations that started World Wars I and II lost them. So why did they start them? Well, a miscalculation, a mistake in judgment. Now to start a world war is serious business; but it turns out that governments make miscalculations and mistakes in judgment. They were the causes of both world wars that have yet occurred. So unfortunately the use of those nuclear stockpiles is not unthinkable.

Actually our government has officially disavowed giving up first use of nuclear weapons. Indeed the whole counterforce policy is a first-use policy. And, you know, I don't know any crazier idea. I've heard Teller before, and you've heard him again now, talking against secrecy. The element of secrecy that's worked hardest on us is to keep reality from the American people. The

American people, and that's one of the main businesses of the universities, are brought up on a prevalent mythology. A very curious example is the presentation of counterforce. You know, Schlesinger announced this is now our policy: counterforce. It was put forth as though protecting the civilian population. One is going to aim at silos instead of cities. It is going to be a soldiers' war. Maybe, if we get everything computerized, as Teller suggests, it will just be computers knocking out computers. Great comfort, but another hoax, because first of all, if that were to happen, and it's almost unthinkable, that the U.S. and the Soviet Union engage in an exclusively counterforce war, and the Soviet Union aimed its missiles only at U.S. silos, the estimate is that that would kill approximately 20 million Americans and at least 1 million Canadians. That's the first point. And then there's an interesting issue: counterforce implies first strike, because how can you retaliate against empty silos? It's only the first strike that will find the silos full. Once the silos are empty, there is not a thing you can do.

But then you have an interesting question: How do you stop a limited nuclear war? — a concept that is about as crazy as anything I have ever heard of. Surely the United States is not going to surrender, and surrender its sponsorship of what I was amazed to hear Teller still call the free world. What we have called the free world includes the largest collection of military dictatorships that has ever been assembled in history. Every time we have had a choice between a democratic government and a military dictatorship, we have picked the military dictatorship. The word is out all over the world that any general who can pull off a coup and take over a country, and then will come to terms with what are supposed to be our interests, will be backed.

And what's happening in Afghanistan now? It's dreadful, shocking, terrible. But I wish we could object with cleaner hands than we have. Because the business of putting in our man and then having him ask us for help is old stuff. That's been our standard procedure. Syngman Rhee, that great democrat, who the students in South Korea finally managed to get rid of, called us in to help. And Diem, and after him Thieu, whom we put into South Vietnam, asked us in to help. Now there is all hell going on in Cambodia. And there are some among the people who are deeply shocked at the Vietnamese contributions to that situation. But don't let us forget that we

left about 8 billion dollars' worth of American weapons in South Vietnam when we pulled out. When one has those weapons, one uses them. That's a good thing to keep in mind. In Cambodia when that tightrope artist Sihanouk went on a vacation, he couldn't come back because, very likely with our connivance, a general had taken over: Lon Nol. Lon Nol okayed every American bombing raid from then on in Cambodia, and a lot of what is happening now in Cambodia can be traced directly back to that. So, yes, I think that Afghanistan is a terrifying situation, and I am relieved in a way to see the Soviet Union clearly and plainly and openly before the whole world getting into exactly the situation that the United States has previously had to occupy alone.

I'm sorry to have left the subject, perhaps to a degree, of this symposium. But I did realize as I do, because I see no way of carrying out limited nuclear war, that the present stockpiles are enough to wipe out all humanity. I ask Teller if he conceives of a situation in which he would approve of the President of the United States getting on the hot line and saying, We've had enough; we surrender. So, when I hear, to me an utter nightmare, Teller's program for the future — (Incidentally, there is standing room only in the next auditorium, where they are talking about the future world. Are we going to have a future world? I wonder.) Teller told his age, and it turns out I'm a little older than he is. So he's had his life; I've had my life. The whole point is that our children, everybody's children, and their children, should have a chance to live. And that's the real problem that lies before us, both of us.

Let me talk a little more reality. I think it must have been clear to all of us hearing the previous speakers on this panel that they are sensitive, decent, and concerned, and that they have jobs to do that they are doing with about as much humanity as one can crowd into those jobs. But you see what a strange world we are in, because none of these things is the same now as it was when I was doing my best scientific work. Science is not the same. The military is not the same. The entire situation is not the same. I don't want to take too long, so let me say as quickly and as readily as I can what I think the real situation is and why I think that's what we really need to cope with.

We in this country are living in a corporate state. This country is pretty completely dom-

inated (and I don't know why I put in "pretty"; that's scientific caution perhaps) by its corporate and financial establishment. That's becoming more nakedly clear every day. One used to take more trouble to disguise it. One has become pretty careless about that. It is perfectly plain.

I think in the hierarchy of things it is the corporate and financial establishment that dominates what is euphemistically called the Defense Department. We don't have a War Department any more. Every war is now on each side a war of defense. The aggressor is always on the other side. In our country I believe that the Defense Department is pretty well at the beck and call of the corporate establishment. But that isn't any mystery either, because I believe that is true of the American government. I think that anybody who supposes that Jimmy Carter has much to do with running the country needs to wake up. He doesn't. The answer to the serious disparity between what he announces he wants to do and what actually happens is that what happens is the corporate solution.

I think it's rather interesting that in the Soviet Union and in China this relationship is reversed: I think that there the military runs the industrial complex; here I think the industrial complex runs the military. It's curious to read Proxmire's announcement each year of how many higher officers in the Army, Navy, and Air Force had retired to become corporate executives. As far as the Defense Department using corporate material, they don't usually retire for that. They just come in for a while and run things and then go back to their corporations. Once in a while they stay, but the other chain of events goes on all the time. A prominent recent example of that is Alexander Haig, who was made a four-star general for his services to Dr. Kissinger, who just retired to enter corporate life.

Now there are certain elements, which I haven't had any conversations about with even the convener of this meeting or with the gentlemen who spoke to us from DOD laboratories before. But I wonder to what degree they might be bothered by an undercurrent of deception and obfuscation and delusion of the public that is connected with the entire defense enterprise. Within this subject let me just mention a few elements. I was shocked to learn a while back that of all the hydrogen-bomb work, all the nuclear weapons, R&D, production, and monitoring, none of that goes under the auspices of the

Defense Department or is charged to Defense. It is Department of Energy stuff, and it is charged to Energy. Before the Department of Energy was put together, this all happened under ERDA, the Energy Research and Development Administration, of all crazy things. It may have puzzled some people that one could move Schlesinger out of the Defense Department and make him the energy czar. That may have seemed a little strange. But it is still stranger that as Schlesinger left the post of heading the Department of Energy, he was replaced by Charles Duncan, who was the Deputy Secretary of Defense and brought with him into the Department of Energy a whole staff out of the Pentagon.

How does that kind of thing happen? Perfectly simple. The major business of the Department of Energy is nuclear weapons. And it is the Department of Energy that runs the major nuclear-weapons research laboratories in this country: Lawrence Livermore and Los Alamos, through the University of California, and Draper Labs, associated with MIT. The last report I've seen from the Lawrence Livermore Laboratories says that only 51 percent of their budget was going into weapons R&D. Actually everyone who has examined that situation realizes that other portions of their research effort, such as the laser fusion research, still are very much defense related, and that something more like 70 percent, perhaps 75 percent, would be a fair amount.

Then we go over to another supposedly civilian agency primarily concerned with research and extending the boundaries of science: NASA, the National Aeronautics and Space Administration. I asked Proxmire's office whether NASA had specific formal arrangements with the Department of Defense. No, I was told, there is just a recognition of what he called common interest. About 2/3 of the space-shuttle program is military. That's a 10-billion dollar program. In 1978 there were 112 military satellites launched: 91 by the USSR, 19 by the U.S., one by China, and one by the U.S. for NATO. Against 112 military satellites in 1978, 42 were put into orbit for peaceful purposes.

I am not in a position to evaluate the real meaning of this situation. But let me just say something that I hope is sensible. In spite of the fact that Mr. Teller has been telling us for many years now that the Soviet Union is ahead qualitatively and quantitatively, all my other weapons experts, the Bulletin of the Atomic Scientists, and

all the best information I can get says the contrary. Now something has happened in the last few years, and that was apparently the hope of being able to make better arms agreements — what are called limitation and control agreements. The thought is, Yes, the Soviet Union is going to have to come up close to parity. Now my best information is that it started way behind. If it was to come up to something close to parity — and by now I hear that it has reached essential parity — then it would have to increase its armaments faster than we were doing. Right? So one starts by saying the rather sensible thing that we need to get control of the arms race and, for that to become possible, we need to have something like parity or the Soviet Union won't play. That implies that the Soviet Union, to catch up, would have to go faster than we for a while. So immediately the cry goes up, the Soviet Union is going faster than we; it's spending more money than we. And maybe this is part of its putting more military satellites into orbit than we.

Of course there is a danger: will the Soviet Union stop at parity? But that immediately throws us into this utterly insane world in which one supposes that those weapons will never be used, and my worry is that, yes, they will be used. That's not just the worry of some people who are off in the sticks. That's in the cards. All of history is behind that. And the crazy thing is that we're coming very close to a war situation right now.

So I think there's no need to belabor these things much further. I have a few notes here and there. I see that the Defense Department has asked for and obtained permission to build a plant to make binary nerve gases. Binary nerve gases are handled more safely. They are mixed in transit, so that each part of the binary is safe if it escapes. Nerve gases are to be added to those horrifying, completely nonselective weapons of mass destruction that create this nightmare of a world into which we put our children and their children. Incidentally the governor of Oregon and Senator Hatfield have just complained that the old stocks of nerve gases are leaking, and they want them removed.

A curious thing about the so-called defense program is its redundancy. How much overkill can you put into a program? You can kill someone only once. You can destroy a city only once. I understand it, one of the strategic problems with the American nuclear-weapons stockpile is

eventual lack of targets. The second bombing of the same place doesn't help much. The Russians follow another strategy. They so far have had many fewer warheads with very much bigger payloads. In fact my friends in talking about the Soviet Union versus the United States cheer us all up by saying we have 2-1/2 times as many warheads and never mention the fact that the Soviet Union has about twice the payload, the weight, of ours. The Soviet Union doesn't want to rely so much on accuracy.

Mentioned earlier in this session was the extension of scientific horizons out of the space program. Out of this very meeting of the AAAS, and I am reading from the newspaper, one factor almost assuring the survival of the shuttle program, the session organizer Logsdon said, is that the United States military plans to use it heavily. Robert Davis of the Aerospace Corporation of Los Angeles, which works closely with the Department of Defense, said, "We are only beginning to appreciate the military potential of space." And then out comes the nightmare, the same nightmare that Dr. Teller was describing to us. "In the next decade the military satellites might well be able to control the movements of robot weapons on the ground or in the air, relaying commands from persons or computers on the opposite side of the globe."

To me, one is closer to reality by quoting, as I am fond of doing, that departed Senator from Georgia, Richard Russell, who in a patriotic speech to the Senate, speaking of the effects of nuclear war, said, "If we have to get back to Adam and Eve, I want them to be American; and I want them on this continent and not in Europe." Two people, one hopes of opposite sex and fertile, remaining out of the American population, but free, because there's nobody else around.

I said, and I deeply believe, though it sounds simplistic and it sounds like a devil theory, but now I think it's simple reality, we're in a corporate state. And I believe that is the force dominating not only the Pentagon but our government as well. I carry about with me one of the most illuminating documents I know. It's the 1978 list of the top 100 arms contractors in the country, published each year by the Department of Defense. It's very interesting to explore and full of interesting realizations. The first realization is: there isn't a corporation the name of which I can recognize, that isn't on that list. I've

played a game with audiences. There's no time to play it with you, but I'd be happy to. The game is for you to name me a corporation, and I will read to you where it stands on this list. For example, the newspapers have been filled with the finances of the Chrysler Corporation. Astonishingly Chrysler is number 13 in the top 100, with arms contracts in 1978 of 742.5 million dollars. No word in the newspapers about this 3/4 of a billion dollars. I want to tell you something strange. This entire enterprise is kept secret from everybody but the business community. It's not public at all. I happen to be a person who is living now as a retired professor on a fixed income during an inflation period, and a pretty small income incidentally. So I have stocks in a number of the corporations on this list. I want to tell you that in my experience I have never seen the presence of a Defense contract mentioned by as much as a phrase in any quarterly or annual report of any corporation in which I hold stock. That's all undercover stuff.

Let me tell you something more. I was surprised when you were talking about the military spinoff that you didn't mention nuclear power. Nuclear power in my book is the direct spinoff of the nuclear-weapons business. And they are still two sides of the same coin. To give you an example, the two principal makers of nuclear power reactors in this country are General Electric and Westinghouse. So I look at my list and see that Westinghouse is number 18 in arms contracts, with 539 million dollars in contracts in 1978. And that brings me to General Electric. General Electric is number 5 in arms contracts, with contracts totaling 1 billion 786 million dollars in 1978. You never heard about that, did you? But that's the way it is.

I've already had a signal to stop talking, but I want to say one more thing. Something strange happened last night: A resolution that's quite hard hitting to try to bring the arms race under control had been submitted to the Council of the AAAS. Nothing like this has ever happened before. And it passed without change. So I have this resolution in my hand. To me the thing with the most punch that it asks for is completion of the Comprehensive Test-Ban Treaty. Ladies and gentlemen, since 1963, which is the date of the Partial Test-Ban Treaty, we've had 16, going on 17, years of pure delusion regarding what's fondly called arms control and arms limitation. The first casualty in this situation was the word disarmament.

The trouble with it is that it means something, it means fewer arms. You haven't heard anything about disarmament in official documents for a very long time. Its place has been taken by arms control and arms limitation. Those are meaningless terms. You can control arms up or down; so far it has always been up. And no matter how far up they go, they will never be limitless, they must always be limited.

Let me add on a sad note. We're in this strange world that I hope I've been saying represents simple, straightforward reality, though sometimes that's the most surprising thing one can talk about. One of my real shocks, painful shocks, that I've lived with since 1975 was the realization that by then we had already entered the era of the corporate professor and, incidentally, the corporate university president. There is a very distinguished list of eminent scientists, mostly physicists, who were sitting on the boards of directors of major corporations, including the corporations on this list, major corporations both in the energy business and the arms business. There is no crime in doing that. The only difficulty is that we have to know it, and one is never told it. Science, even at the most basic level, is not without sin, as once it was; and this is an element in that situation.

I'm afraid I've talked too long. Thank you.

DISCUSSION

David Triantos

I'm sorry that we don't have more time, but Dr. Teller has to leave promptly at 12 to catch an airplane, and he would like a minute for a response.

EDWARD TELLER

Three obvious points of fact. First, without secrecy the differences between myself and the last speaker could be more fully and completely discussed, and that I wish. Second, Professor Wald was wrong in stating that I have for years stated that the Russians are quantitatively and qualitatively ahead of us. I have said for a few years that they are quantitatively ahead. That they are qualitatively ahead of us has become known only in the recent past. And third, I have not in this speech, and not on any other occasion, said that a nuclear war can be limited. I said, humankind will survive a nuclear war. To stop a

nuclear war before one side is completely defeated is impossible, in my opinion. Our purpose of preparedness is to put arms into the hands of those who, no matter how some people of the society talk about it, are a free society, together with England, together with France, together with some of our other friends. This freedom should be defended by deterring the Soviets from starting a war. Once the war is started, we'll have to fight it, but I have no hope to limit it. My aim is peace. I claim that my aim for peace is more realistic than that of my friend, Professor Wald.

DAVID TRIANTOS

Are there any brief questions of any of the speakers?

STAN GLANZ

My name is Stan Glanz. In the early 1970s I led a group of students at Stanford University who did a fairly extensive study of Defense Department research in the universities, which was published rather widely at the time. I would like to amplify some of the things the earlier speakers said, and also some things Professor Wald said, from the perspective of someone who is from a different generation. First of all, I agree with all the initial speakers. I think the quality of the science and the quality of the management by the Defense Department is excellent. But I think, at least in the early 1970s, it led to something which is fundamentally incompatible with the university and with truth and with honesty, because when we looked at the contracts for grants, albeit they were for excellent science, there was no question in my mind and those of the people I was working with that they were all things that had obvious relevance for the military, often over a longer term, but there was always an obvious military connection. In fact the military was very open and honest with us.

But the faculty was absolutely unwilling to confront the realities of what they were doing, and the obvious uses and moral implications of what they were doing. And I think that this was fundamentally destructive. Very important to the university are honesty, objectivity, and openness. I think there is one place a great deal of damage has been done to the universities by their connections with the Defense Department. For this I do

not fault the Defense Department; I think they're doing their job. But I think it is something the universities hadn't then and still haven't really come to grips with. We had no problems at all with the professors who claimed they were supporting the Vietnam activities. They had an unambiguous position. The problem we ran into, and the people we saw having the most difficulty, were the professors who claimed they were opposed to the Vietnam activities yet at the same time were doing things that even in the short term helped to facilitate those activities. When people talk about skewing the universities and moving science in certain directions, I think that can be done while maintaining the caliber and quality of science, but I think many of the points made by the earlier speakers miss the mark.

AUDIENCE MEMBER

I have a question for Professor Wald. You assume that corporations control the military and that it's a bad thing. Why do you feel that way, and what do you suggest as an alternative?

GEORGE WALD

It is deeply planted in the American system that the military is under civilian control. We have to reach back a little into old-fashioned thoughts about what democracy is all about, that I've lived with through a pretty long life. Civilian control of the military doesn't mean working the military so it can make more money out of defense contracts. It means governing the military to the maximum advantage and welfare of the American people. I think that one could imagine civilians at top levels of the Defense Department who did not come directly out of industry and did not then go back home again. That's been the common practice.

The trouble with corporations is that they have a single-minded pursuit of profits. They even make an ideal of it, and virtually nothing else. I've dreamed up idealistic corporate executives, but there's a little thing called Gresham's law that says bad money drives out the good. In the competition that exists there is no top corporate executive who, for moral reasons such as contributing to the cessation of the arms race, would refuse an arms contract, because that arms contract would immediately be taken up by some competitor. He would be in exactly as much

trouble as if he had taken it, and he would have lost that contract. So you see it's one's duty to the stockholders to push that business to the limit.

AUDIENCE MEMBER

Parenthetically I can't help but observe that there are other speakers right next door who are talking about the world of the future as if there is no impending nuclear war, and the place is packed with people, probably 10 times those in here, not facing reality. They are in a dream world, and they think our reality is in the realm of science fiction only.

RADIO NEWSWOMAN

I have a question for the representatives from the Department of Defense laboratories. For people that work at the Naval Research Laboratory, or at Los Alamos, which is not directly DOD but indirectly through the University of California, is there a conscious attitude that people are doing research problems that could lead to the deployment of first-use offensive weapons, whether they be biological weapons, undersea missiles, or whatever they might be, not necessarily atomic?

GEORGE GAMOTA

There is a difference between basic research and applied research, or between exploratory development and advanced development, and it is very hard to segregate the work you are doing, particularly of a basic nature, and what the long-term impact is going to be. I am sure the people working for the Department of Agriculture today might conceive of something that may help defense in 2 or 3 years from today and in fact may have an impact much greater than anything the DOD is today supporting.

People who do work in the laboratories don't sign on the dotted line saying, Yes, I am conscious of this or I am not conscious of that. Certainly people who are working there and dedicated to the principle of staying free by being militarily strong will support that mission.

RADIO NEWSWOMAN

If I follow your answer through to the next question, it would imply that everybody doing

scientific research in the United States in any sector is potentially contributing to the defense apparatus, consciously or unconsciously.

GEORGE GAMOTA

Of course. Boolean algebra was developed more than 100 years ago, and today Boolean algebra is very much of use in the Defense Department. Going back 100 years, was Professor Boole really aware of the defense implication? The answer is no. Of course science and technology are interlocked with defense, and there is no area of science or engineering that I can categorically say will have no impact on defense. We have seen surprises. If you went back to the start of World War II and asked the Defense Department what the most important things were they were working on, the three most important things that made the difference in the war were not even on their list. Radar wasn't on their list. Nuclear power wasn't on their list. Today you can make a 20-year projection, and you can ask DOD what are their most important areas, and we will provide a list. But I can assure you we will all be surprised, even as close as a year from now. You cannot categorically deny that any area will have an impact on defense.

RADIO NEWSWOMAN

But I'm trying to understand; when you choose to work at NRL instead of at Berkeley, what is the difference in the attitude toward your work or why you're doing it?

GEORGE GAMOTA

I don't work at NRL or at Berkeley, so I can't really answer that. Maybe Dr. Salkovitz could answer that.

STAN GLANZ

This is exactly the same question discussed at great length when we were doing our work in the 1970s. Edward Riley, who was then the Assistant Director of Defense Research and Engineering, which may have been a predecessor position to yours, said, in the context of the Mansfield amendment, which was driving people crazy at the universities, that he didn't believe it is possible for any faculty member to be versed in DOD's needs. But as the faculty sought support

from DOD, they were telling their campus constituency that their work has no military uses, but a few of the faculty had to face a statement of military relevance. Whether the few of the faculty at Stanford needed their knuckles rapped, however, is a minor point. The main point is that DOD now exempts all scientists from grappling with the key moral issue of the uses to which their research results will be put. I think that's the question this woman is trying to get at. And you're saying, Well, you can't tell what something is going to be used for definitely. And that's absolutely true. But you can have a reasonably good idea of what you got in mind, at least in the short term.

GEORGE GAMOTA

Of course we do; of course they do.

STAN GLANZ

That's the point. I think that most people working in these laboratories, that I know of, will try to sidestep this moral question of what are the uses to which the work they are doing will be put. Personally I am not in favor of disarmament. I've been in Eastern Europe, but I think the Russians are bastards. But at the same token, I think that hiding from the moral implications of things you are doing doesn't make us any stronger. And all the nuclear weapons in the world haven't kept the Russians out of Afghanistan. There is a different problem, which I think relates much more closely with what Professor Wald was talking about.

EDWARD SALKOVITZ

I want to make some comments on this point. I worked at the Naval Research Laboratory, I have taught at universities, and now I'm at ONR. There are several kinds of people who come to a laboratory such as the Naval Research Laboratory. Some young people come primarily to make a name in their field. There are excellent facilities at NRL and in almost any field of science. There are outstanding people at NRL. There are people who want to do their apprenticeship there. They do not want to teach. They want to do first-rate research with first-rate people and first-rate equipment. They want to publish. There are others who go to a laboratory such as

the Naval Research Laboratory (and I hope this doesn't surprise anyone) for purely patriotic reasons. You are aware of salary limitations in the Civil Service. Clearly, with the responsibilities we three DOD speakers carry, we are paid far less than our industrial counterparts.

DAVID TRIANTOS

Any other brief questions?

RADIO NEWSWOMAN

One thing that disturbs me about a discussion earlier is this: It is too easy to think that because virtually every aspect of science and technology has implications for military uses, that science and technology itself is a bad thing. In the 1960s there was an antitechnology backlash. Teller pointed out you cannot really draw the line between military and peaceful applications of certain knowledge. For example, a person might be working on a fabric that can be used every day, but that fabric might also provide a more efficient parachute or a soldier's uniform or something like that. Or if we increase our production of agriculture, which we want to do, that can be used for self-sufficiency in time of war. I think the line should be made very clear between the types of things you invent and the applications, because otherwise we would be in trouble and would be going back to caves.

How do the members of the establishment here feel about what Professor Wald referred to as an undercurrent for deception: for instance, the Department of Energy being used as a budgetary item for actual Defense purposes, and such things as the space shuttle?

GEORGE GAMOTA

I think what we have here is the problem of useful communication for information. I don't think there is any deception here. There is a question of having the information and disseminating it to the right people and the right person seeing it. For example, the list of the top 100 industries is a paper that comes out yearly unclassified and goes out to people who are interested in it. The list appears in the New York Times, the Washington Post, the Wall Street Journal, and various journals. The top universities who are supported by DOD is also a paper

that I get 200 copies of every year or so, and people send in requests, and I send it to them. Of course I don't go out and have press conferences and say these are the universities and these are the industries. Professor Wald knows very well that anyone who wants it can get it. It is a question of whether we should have a public relations effort to expound on items like these. If people are interested, we will supply the information to them.

The fact that NASA has been working on the space shuttle and that some of those have impact on defense missions has been known to most of the public. With many of the things that have gone on in the past, we in DOD have looked very closely to see what application values those efforts have. And I can assure that if there are application values, we will try to use them. The fact that the Department of Energy has nuclear responsibility is something that has been ingrained in our government from day 1. Congress said it; it's national policy. I don't think you can fault the Defense Department for setting up the Department of Energy for control of nuclear matters. That is the way Congress has set it up, and it's the will of the people.

GEORGE WALD

Incidentally, the Department of Energy budget for nuclear weapons, R&D, and production is 2.6 billion dollars, going to 3 billion dollars this year. It is quite true this information is available if you ask for it, but there is a sort of conspiracy of silence. Any number of other things would be of great surprise, only because one hasn't asked for the information. If you do ask, you can get it.

I want to say one thing about what George Gamota said in response to a question. Yes, it's true one doesn't know beforehand what aspect of either scientific research or what have you, covering medicine, physics, geology, anything might be put to defense use. That's a description of the nightmare that we've gotten used to. The truth of the matter is that every aspect of increase in information, knowledge, and understanding is being watched carefully for possible military use. I thought my own work to be about as useless and impractical as anything could be to the military, but I had a call one day from a doctor in the Edgewood Arsenal saying, You're the man we

want to consult on temporary blinding agents. This was during the Vietnam war. Anything goes in this regard.

Also I want to say a word about the cautionary thing the young woman said. My own simple rule of thumb is: Know all you can, but that's for society as a whole, not for just me. Know all you can, but do only those things that will benefit society and make a richer life. And that's where the trouble comes in. We have no such selection principle involving what you do among all the things that it's possible to do.

[The transcript ends here, because the recording tape ran out. A question followed which Professor Wald answered by saying that although we are horrified by one-party foreign countries, we also are actually a one-party country and that we need genuine politics in this country. Several final comments then followed, one comment being that whether one thinks we have a corporate state or a one-party state, in Russia a discussion such as the preceding would be impossible, and another comment being that the people of this nation actually are free to change the purpose of science if they really want to.]

ADDENDUM

David Triantos

The preceding is a transcript of the presentations at the AAAS symposium. I added this initial section of an addendum so that, during preparation of this transcript for printing, the speakers could read this section, review their own and the other presentations and then, if they desired, add brief reflections and updatings as following addendum sections. A section was added by Dr. Teller, but the other speakers felt they did not need to add anything.

A specific purpose I had in organizing this symposium was to publicize how much the Defense Department does advance science. But because the Defense Department advances science in response to national demand for a strong military in a world of competitive nations and because the military advances science to get new warfare hardware, which saddens me and is a nightmare to Professor Wald, I also had a more general purpose in organizing this symposium. That purpose was to ask, assuming the world's nations could find peaceful cooperation and disarm, how much popular demands other than

military strength might advance science. Getting an answer in this 3-hour symposium was, of course, not possible.

The speakers excellently described the military's strong support of science, with the wealth of material presented being ample justification for printing this document. I think the surprising ways research initiated with a military goal can find application outside the military can be greater than the surprising ways research initiated with no military thoughts can be applied by the military. But in describing the military's support of science, the speakers revealed how deeply competitive nationalism is woven into our world tapestry. However, some of the comments revealed what may be a new pattern emerging.

Furthermore this symposium was one of many at the AAAS meeting. Other symposia discussed the coming age of computerized communications, when any person anywhere in the world will be able to directly access the ideas of any other person. The military is strongly supporting communication technology so that all the military elements of the nation can be linked together and respond quickly and efficiently as a single organization when a threat is perceived. Perhaps computerized communication technology that is expected to strengthen the military will instead let people of the world tell each other they have become free individual members of one worldwide society and no longer need the military. Perhaps then we can learn what our real problems are that need application of our increasing ability to solve problems with technology.

I will slightly expand a simple model of the evolution of war that was mentioned by Victor Weisskopf during a speech titled "Science, Technology, and Culture" at another session of this AAAS meeting. We once had castles as a military technology, but the new military technology of cannons made them obsolete. Hence castle-versus-castle fighting ended. We backed off to town-versus-town and city-versus-city fighting and then backed off again to country-versus-country wars as newer military technology arose. More recently we have had continent-versus-continent warfare. At present, as the speakers made clear, military technology makes even that scale of warfare obsolete, so that with no real defense we look to deterrence. The world no longer has a larger dimension for backing off into a new realm of warfare. Fortunately we are not yet ready to populate space and have star wars.

Maybe warfare thus has evolved into obsolescence and, if the terrorist problem can also be solved, we can turn to being a world at peace.

The old military technology of a castle has become a central symbol of Disney Land and Disney World fun and happiness, with the old military role of the castle being practically forgotten. Let all our military technologies become central to a worldwide Disney World with ever-new attractions, in which world we will find a richer and happier life as both free individuals and members of a world organism. Maybe that will be the organism ready to populate space.

EDWARD TELLER

It is, of course, impossible to disagree with Professor Wald in one respect: an all-out nuclear war would be a nightmare. It would be a nightmare of nightmares.

It is possible and necessary to disagree with unscientific statements that the nuclear war would be the end of mankind. Even in the United States there would be many millions of survivors—needless to say, survivors who will be miserable to an almost unimaginable extent. Any statement that the human race would be wiped out is an unfounded unscientific exaggeration, justified only by frequent repetition—a method inappropriate in a discussion where we try to preserve some respect for accuracy of statements.

There was, however, a serious omission in my statement in the case of the Soviet Union: a great majority of the people would survive. Indeed, those killed would be horribly numerous but still much fewer than the Soviet people who perished in the second World War, because the Soviet Union is taking civil defense more seriously. It is prepared to fight and win a nuclear exchange. After such an exchange, they would have enough weapons left over to menace and rule the rest of the world. They would demand and get any food, any machinery, any slave labor that they want. Lack of preparation on our side is apt to lead to these truly dreadful consequences.

Perhaps among our sins of omission the greatest one is that, unlike the Soviets, we do not work on civil defense, we are not prepared to defend the lives of our citizens. Due to the strength of the United States in its peaceful economy, it may not be too late even today to take

the necessary actions that will provide the needed passive and peaceful defense for our citizens.

Professor Wald pointed out quite correctly that both he and I had a long life and that his, indeed, was a little longer. But I can claim, not too happily, that I had two lives: one in a totalitarian country and one in a free country. (Incidentally, my totalitarian country—the Hungary of my

youth—is a mild version of what you find today in the Soviet Union.) Professor Wald claims that the United States today is totalitarian for all practical purposes. I have the full and sufficient knowledge to deny this. To preserve and defend the free world is a purpose for which our work and even our lives may not be too high a price to pay.